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Technology Center

An Exploratory Analysis of Responses to Geographic Information System Adoption on Tri-Service Military Installations

by Brian Cullis, United States Air Force Academy

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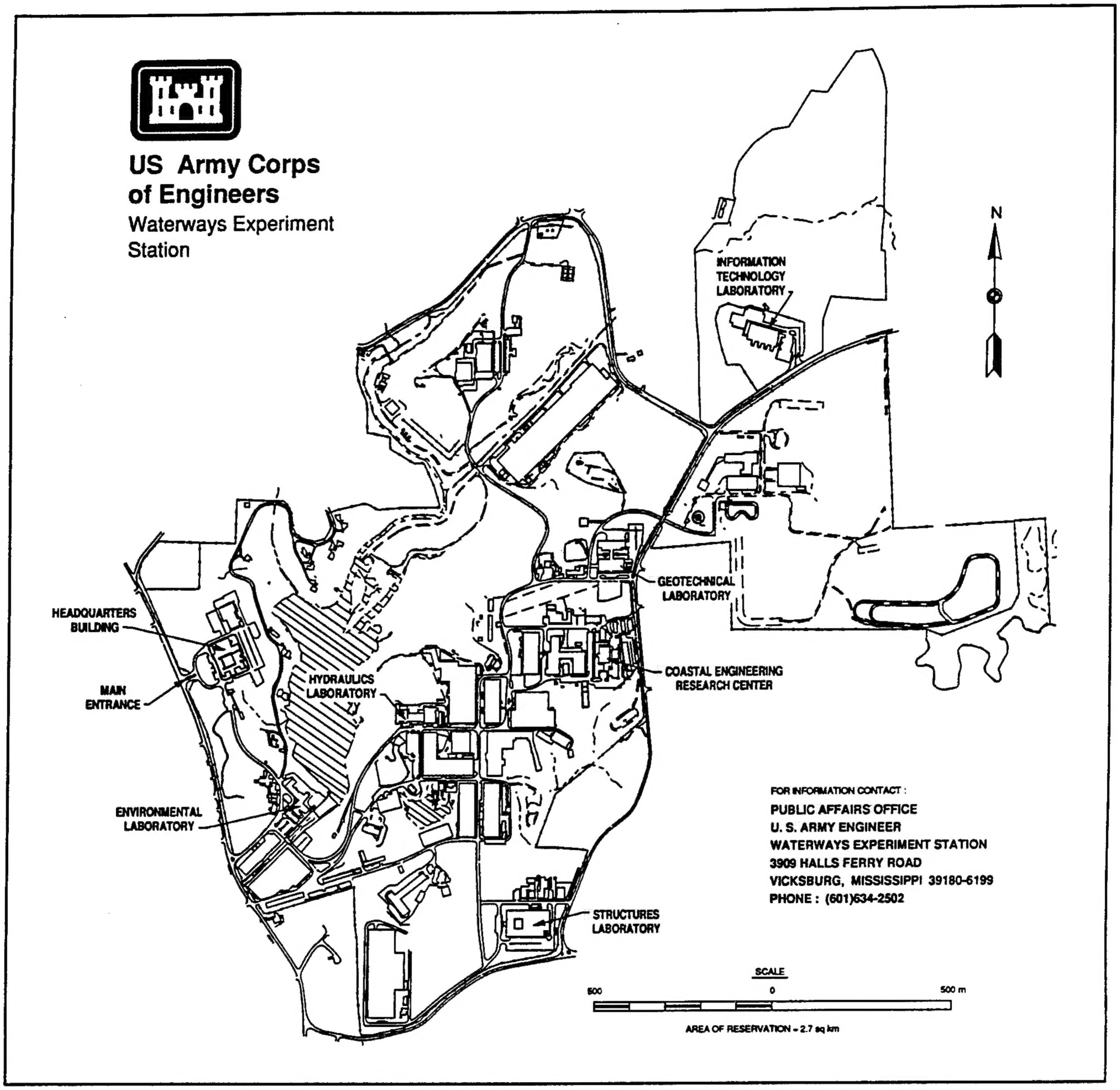

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Preface

This report details a study of GIS programs across a representative sample of organizations on military installations that were relatively early adopters of GIS technology. Major Brian J. Cullis (USAF) served as the principal investigator and performed this work while doing his doctoral research at the University of South Carolina in the field of geographic information processing.

This research was funded by the Tri-Service CADD/GIS Technology Center, Information Technology Laboratory, located at the U.S. Army Waterways Experiment Station. Major Brian J. Cullis (USAF) was the author of this report, and the Tri-Service Center POC for this study was Mr. Ken Cook. Draft versions of this report were technically reviewed by Ms. Laurel Gorman of the Tri-Service Center. The statistical analysis presented in this report was reviewed by Dr. Mary Ann Leggett, Engineering and Scientific Applications Group, Computer-Aided Engineering Division, ITL

The research was performed under the administrative supervision of Mr. Carl S. Stephens, Chief, Tri-Service CADD/GIS Technology Center, and Dr. N. Radhakrishnan, Director, ITL.

At the time of the publication of this report, Dr. Robert W. Whalin was Director of WES. Commander was COL Bruce K. Howard, EN.

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1 Introduction

GIS technology has been diffusing across defense installations for almost twenty years. Several laboratory, headquarters, and grass-root initiatives by the services resulted in a variety of GIS software packages being adopted. Trade journals have reported a sample of the diverse GIS applications now occurring on military installations (Conry and Goldberg, 1994; Dilks and Finney, 1994; Foresman, 1993; Bruzewicz, 1992; Elliott, 1991; Goran and Finney, 1991; Leipnik, 1993; Talbot, 1991).

All those organizations implementing GIS, regardless of military branch, software or applications domain, have likely experienced the same frustrations as their GIS peers in the private and public sectors. The Center was chartered, in part, to develop policy to mitigate these frustrations and facilitate successful GIS implementation across tri service installations. Therefore, this could best be accomplished by the Center acquiring an informed appraisal of current GIS adoption outcomes to date.

Purpose of the Research

The purpose of this research was to develop and employ an assessment scheme which captured the general implementation characteristics, processes, and outcomes to GIS adoption within organizations who had used the technology long enough to form a discernible profile of adoption response opinions. A secondary research goal was to demonstrate that regardless of the computer platform, software suite, applications domain or military service, there were *common* social and technical factors predictive of successful GIS adoption.

Limitations to the Research

Investigating the adoption of a technically complex technology (e.g. GIS) within a socially complex environment (e.g. military installations) presents significant problems to a researcher seeking a concise, accurate picture of the adoption process and subsequent responses. Therefore, it is important to stress three key research limitations.

First, the models and trends reported herein must be viewed in their historical context as general summaries of the GIS program *as of the survey dates*. However, while many of the dynamic attributes have changed since the site visits, the larger technology adoption process is rooted in much slower-moving social and institutional frameworks rendering the noted 1994 trends still very much relevant.

Secondly, this study is limited in its implementation perspective. Only a finite, practical number of GIS implementation facets were examined from among a virtually unlimited number of possible variables. This report should be viewed as an *initial* and *exploratory* attempt at describing GIS *post-adoption* behavior. Constructive criticisms will help to develop more effective means of conducting future GIS adoption response studies for the tri-services.

Finally, this study is limited in its scope of GIS programs evaluated. This report is *not* a reflection of the *current* total use of GIS technology across the tri-service community (including the US Army Corps of Engineers). The research focused on a *representative sample* of *field* organizations on military *installations* who had a *mature* GIS implementation with an *experienced GIS user base* capable of providing *informed* opinions about their *responses* to GIS adoption. This sample exhibited an environmental applications bias for reasons to be described later in the report. The need for a sample of mature implementation sites unfortunately excluded a large number of programs in pre-mature stages of development as of the Fall of 1993.

The report is structured to allow readers to focus on a specific implementation topic or actor. Chapter 2 will describe the general methodology used to conduct the research. Chapter 3 presents general organizational profiles of the GIS implementations using data gathered from GIS managers. Chapter 4 includes the GIS adoption opinions of senior managers and GIS managers gathered through structured personal interviews. Chapter 5 describes those individuals who were making actual "hands-on" use of the organizational GIS. Chapter 6 presents the findings of the scientific modeling process used to identify what issues had significantly influenced GIS adoption responses to date. Chapter 7 assesses the opinions of the direct GIS users towards the role of satellite-based positioning and remote sensing technologies. Finally, Chapter 8 summarizes the findings and provides general recommendations for the Center to consider as action items in effectively supporting tri-service CADD/GIS technology adoption.

2 Research Methodology

Conducting Innovation Adoption Research

An innovation is defined as a technology actually being used or applied for the first time (Utterback, 1974). Five relatively distinct phases to the innovation adoption process can be seen in Figure 2-1. The model portrays how beyond the initial adoption *decision*, the more important adoption *response* during implementation will determine the extent to which the innovation is actually used. Should an adopter become frustrated and disillusioned during the implementation, they will likely decide to discontinue their use of the innovation.

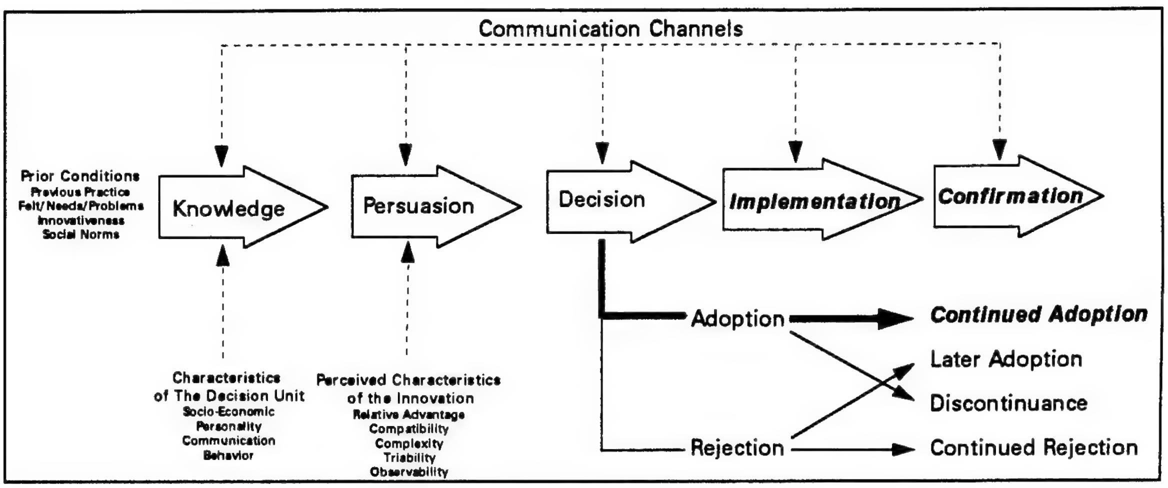

Figure 2-1. Stages in the Innovation-Decision Process (Rogers, 1983)

Detailed investigations of what happens while attempting to transform the rhetoric of potential innovation benefits into reality are "exceedingly difficult" and "often discussed but rarely studied" (Pressman and Wildavsky, 1973). The term 'implementation' has been defined in many ways, usually as a process with an outcome of the technology being assimilated within the organization as an operational routine such as word processing (Tornatzky and Klein, 1982). GIS practitioners fall short of this outcome when they describe implementation as "the process of installing and testing the system (Joffe, 1990). More confusion arises when the organizational decision to simply purchase the technology is considered 'adoption success' rather than more practical outcomes such as the actual extent of system use. This research considers the GIS implementation to have ended only when the technology has become an institutionalized, integral part of the adopting organization's ongoing operations and is no longer considered a technological novelty.

All organizations seeking to adopt GIS will discover the process of integrating the technical "means" of their new GIS into their social "ways" especially challenging. An innovation adoption model by Mayo (1985) helps to show why this process can be difficult. Figure 2-2 depicts how a new innovation like GIS will only be accepted and used within a society if it meets not only technical, but also social acceptance criteria. These

technology and social "gates" consist of a variety of extremely powerful influences which determine how well the technical facets of the innovation are absorbed or accepted into the organization. Most organizations tend to focus on just the issues comprising the technical gate (i.e.. hardware, software, and database development) and only begin to appreciate the social obstacles when the intended benefits fail to appear. In reality, every intended organizational GIS user possesses their own personal “social gate" inhibiting their full and complete adoption. This research adopted this model’s assumptions by examining the influence of both technical and social issues towards better understanding GIS implementation outcomes.

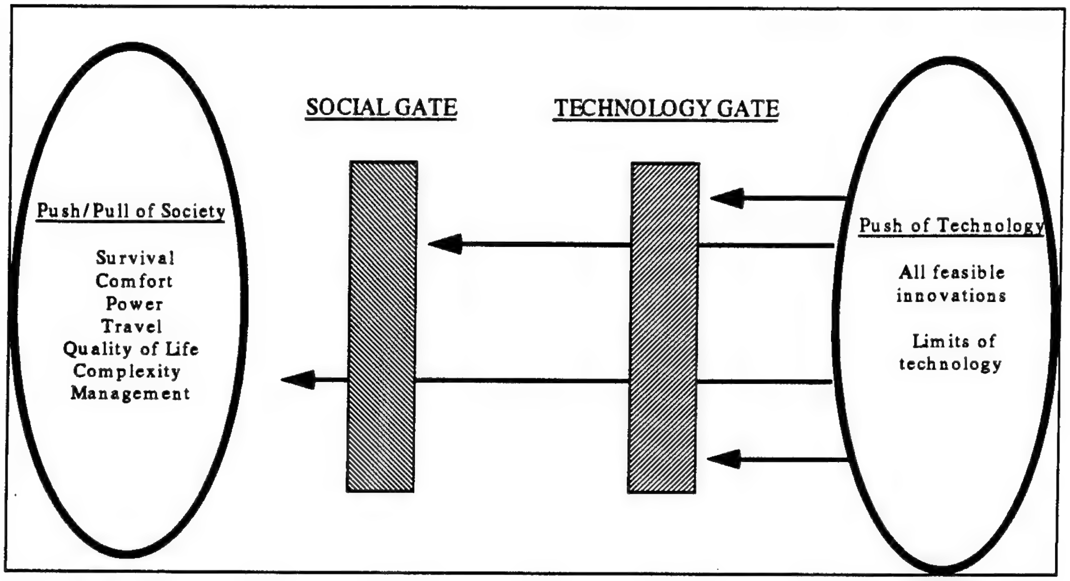

Figure 2-2. Mayo Model of Information Technology Innovation Adoption

The Research Population

The previously defined goals required that the principal investigator find a large sample of field-level organizations who could provide informed hindsight opinions of their GIS adoption. Although there was a legacy of GIS technology use at several defense laboratories and throughout the US Army Corps of Engineers, these two groups of GIS users were eventually excluded from this research program for three reasons: 1) pre-testing of the survey instruments indicated that an accurate portrayal of their adoption responses could not be obtained using the instruments developed for the field users at military installations; 2) the project emphasis found in both the laboratories and Corps districts introduced operational variances not encountered by field users at the installations; and 3) both laboratories and Corps Districts had extraordinary technical staffing compared to the typical field-level installation.

Since there was no tri-service office with a mandate for monitoring the extent of GIS adoption, a preliminary list of potential sites was informally compiled by the principal investigator soliciting any knowledge of GIS technology adoption from a broad array of

service agencies and individuals across the US Army, Navy, Marine Corps, Air Force, and US Army National Guard. A phone survey of the initial 120 organizations identified as potential sites found 69 installations actively implementing GIS technology. A total of 38 organizations reported they had enough GIS use experience to be able to provide informed GIS adoption responses. The GIS managers contacted by phone at these sites reported a cumulative total of 180 direct users of acquired GIS resources, an adequate sample size to allow for a quantitative analysis. Five different GIS software packages were found to exist among the sites. A list of the 38 organizations included in the research is found in Appendix A.

It is noteworthy to comment on the fact that most of the early GIS adopters on military installations were environmental management organizations. The management of environmental resources on military installations has become more challenging over the past twenty years due to an outpouring of new federal, state and regional regulatory guidelines. Faced with the dual tasks of providing both effective mission support and responsible stewardship, innovators within the US Army provided the first impetus for the development and application of a computer-based, spatially-indexed information system. In the ensuing years, a variety of initiatives from laboratories, headquarters, and the field led to a wide array of commercial and public domain GIS software and hardware configurations being used to reduce environmental management complexity. However, the research trends revealed GIS technology has begun to rapidly diffuse beyond the realm of environmental applications and is being adopted by numerous civil engineering and public works organizations to more effectively steward the developed, physical infrastrucuture of their installations.

The Units of Analysis

Successful organizational adoption of a new information technology such as GIS is dependent on more than just the actual system user. The opinions of senior managers tasked with technology implementation oversight have always been found to be key determinants of successful, long-term acceptance. Unfortunately, GIS implementation research conducted over the phone or by mail has typically relied on the opinions of only one individual, usually the GIS manager, to provide organizational opinions of the GIS effectiveness. This research employed a more in-depth case study approach by personally visiting each of the installations to gather first-hand feedback from the following individuals:

1) Senior Organizational Managers. A template of structured interview questions was presented to those managers who were identified by their respective GIS managers as oversight officials for the GIS acquisition and support process. Private personal interviews were conducted with each of these individuals and a short quantitative survey was also administered. Chapter 4 will provide the results of these interviews and survey responses.

2) GIS Managers. Organizations adopting GIS typically task one person with the primary responsibility for implementation. Lengthy, personal interviews were conducted with these individuals. A short quantitative survey similar to the one used with the senior managers

was also administered. The responses from the GIS managers are presented in Chapters 3 and 4.

3) Direct "Hands-On" GIS Users. Those individuals who were making direct use of the GIS were the most important organizational echelon for this research. An extensive survey instrument was first compiled and pre-tested among a select group of tri-service individuals. Every effort was then made to administer this survey to all qualified GIS users during the site visit. A short survey was also administered to the indirect users of the GIS to help surmise the extent of GIS product diffusion. The results of this indirect user survey were obtained to help serve as a baseline for future tri-services GIS diffusion research.

The final research design included the principal investigator personally visiting each of the 38 sites and using the survey protocol portrayed in Figure 2-3. The blending of GIS adoption research methods in this manner increases the validity of the evidence gathered and yields more reliable results. Examples of the specific structured interview questions and survey instruments administered are found in Appendix B.

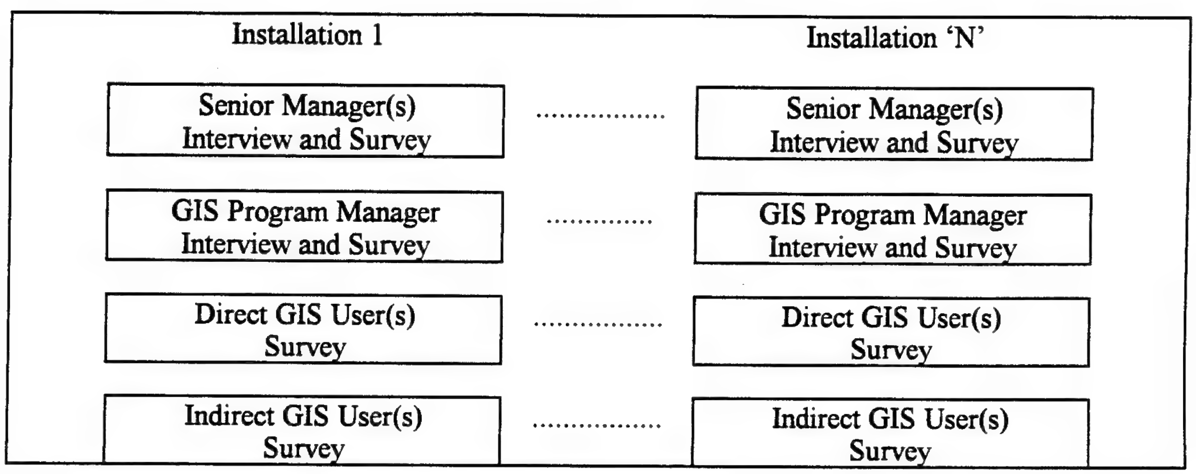

Figure 2-3. Organizational GIS Survey Methods

3 Organizational GIS Adoption Profiles

Descriptive Implementation Traits and Trends

Table 3-1 provides general descriptive statistics more details of the sampled GIS implementations. The average provides a better, less biased estimate of a larger population only when this population's distribution resembles a normal bell curve. The median or middle value of a distribution is a better estimate for the non-normal or skewed data distributions. The variables will be described in this chapter.

Table 3-1. Summary of Surveyed Tri-Service GIS Implementations

Variable	Average	Median
Age of GIS Implementation (Years)	3.5	3.0
Size of Organizations Adopting GIS (Est. Personnel)	50	14
Annual Organizational Budget (Est. Million Dollars)	28	1.5
Personnel Receiving GIS Training in the Organization	3	2
Number of Direct GIS Users/Organization	2.1	2
Number of Indirect GIS Users/Organization	3.3	3
GIS Hardware Costs to Date (Est. Dollars)	127,430	65,000
GIS Software Costs to Date (Est. Dollars)	21,930	10,000
GPS Hardware/Software Costs to Date (Est. Dollars)	17,350	11,500
Database Development Costs to Date (Est. Dollars)	501,520	158,000
Percentage of Total GIS Expenditures to Date Spent	72%	68%
Percentage of Target Database Populated to Date	40	27
Total GIP Expenditures to Date (Est. Dollars)	651,638	275,250

Age of GIS Implementation Figure 3-1 shows a frequency histogram of the age of the GIS implementations sampled. Installations such as Fort Lewis had been willing to assume the increased risk of early GIS adoption in hopes of proving the potential benefits of GIS for accomplishing their environmental management tasks.

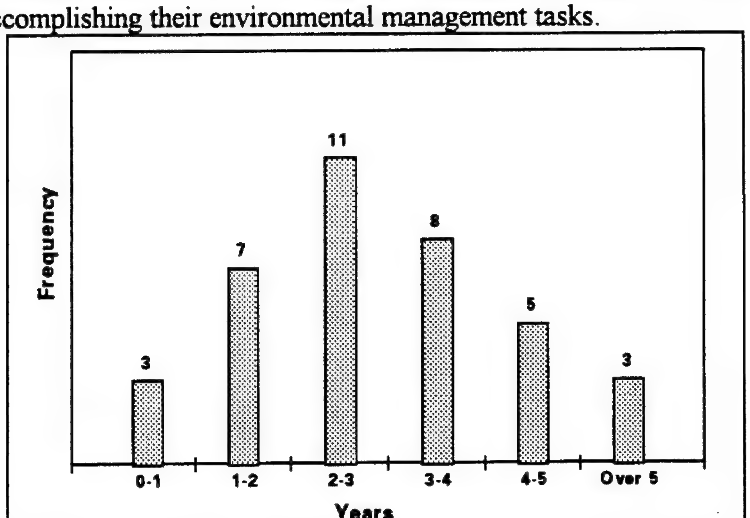

Figure 3-1. Age of GIS Implementations Surveyed

While Figure 3-1 suggests GIS diffusion has peaked, to the contrary there were 55 organizational implementations of GIS discovered during the Fall 1993 phone survey who were either in the initial stages of a GIS implementation or had just begun a serious investigation into GIS adoption. The majority of the new implementations just underway were usually broad in scope and were designed to take advantage of the large CADD databases compiled over the years for infrastructure management. These new initiatives are exciting since integrated CADD/GIS solutions hold tremendous potential benefits for installations.

Size of Organizations Adopting GIS. Edwards AFB had an extremely broad, comprehensive GIS implementation underway with goals of satisfying the spatial data needs of a large number of organizations on the installation. The more typical organization had 14 members since most of the GIS programs surveyed were found within environmental offices possessing relatively small staffs. For example, at Dare County Air Force Range in North Carolina the entire environmental staff consisted of two individuals who were using a PC-based GIS to aid their wetlands, wildlife and forestry management programs.

Number of Direct GIS Users/Organization. Of the 114 individuals who had received GIS training across the 38 installations, only 82 were qualified as current direct GIS users. Edwards AFB provided the largest group of direct GIS users (8). Several of the installations had only a single direct user, this being the GIS manager. This apparently poor return on the GIS training investment was alleviated, in part, by many of these individuals preferring have other direct users generate GIS products for them.

Number of Indirect GIS Users/Organization. The typical installation had three individuals who made recurring use of GIS products generated by other direct users. A majority of these indirect users had been initially provided with formal GIS training with the thought of becoming direct users.

GIS Hardware/Software Costs. GIS managers were asked to estimate their total expenditures to date for GIS hardware and software. There was a notable lack of strict GIS cost accounting especially among those GIS managers who were tasked with other primary duties (e.g. Range Conservationist). Managers on US Army installations found it difficult to itemize expenditures since most hardware, software, and database development costs were funded in lump sums through the Integrated Training Area Management (ITAM) program.

GPS Hardware/Software Costs. Specific discussion of Global Positioning System (GPS) technology used at the surveyed sites will be presented in Chapter 7. This cost-effective satellite-based positioning system had quickly become an integral component of installation GIS programs. Environmental managers were making extensive use of the GPS technology given their frequently large, remote operational areas. Most of the sites had acquired both the hardware and software necessary to post-process the positional data for less than $12,000.

Percentage of Total GIS Expenditures to Date Spent on Database Development. Database development is assuredly the most expensive part of any GIS implementation process and usually constitutes at least three-quarters of the total GIS investment (Aronoff,

1989). The average installation surveyed was on target with this figure (72%). Frequently, organizations view the GIS investment solely in terms of hardware and software costs and are often later surprised at the unanticipated costs of database development.

Percent of Target Database Populated to Date Though the sampled installations had begun implementation more than three years prior, the typical program had populated only about one-third of their targeted GIS database.

Total GIP Expenditures. The total estimated expenditures on geographic information processing technology (GIP) included the organization's GIS hardware, software, database development, remote sensing and GPS costs. Since a few very large implementations skewed the data, the median GIP expenditure of approximately $275,000 to date on spatial technologies is more accurate.

Adoption Path for GIS Technology. During the private interviews, senior managers were asked whether their unit's adoption of GIS was best described as: 1) self-initiated or "bottom-up" approach; 2) developed by headquarters elements and made available to units; or 3) directed by or "top-down" approach. Almost all the sites considered their adoptions to be self-initiated (Figure 3-2).

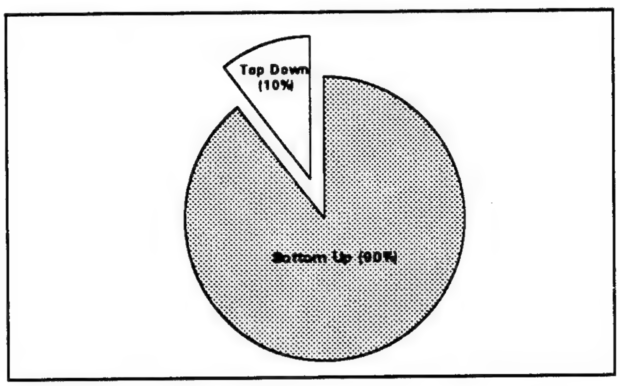

Figure 3-2. Perceived GIS Adoption Path by Tri-Service Personnel

GIS Manning Authorizations. GIS implementation is a time consuming task requiring a significant amount of manpower. An often misquoted GIS adoption benefit is a decrease in manpower requirements due to the efficiencies created by automating tasks previously accomplished through manual means. In truth, conducting an in-house GIS implementation typically requires *more* personnel during the initial stages since the mission must still be accomplished while the GIS is under development. A key determinant for manpower needs is obviously the scope of the implementation. A distributed GIS across several organizations requires more support than a PC-based GIS for a single office.

Figure 3-3 notes the majority of installations were addressing the responsibilities of a GIS manager as an "additional duty". The site visits found three primary reasons for the lack of manpower authorizations to accomplish GIS program management; 1) senior managers were not fully aware of the significant man-hours required to implement a GIS; 2) there were no standard position descriptions available for the new GIS requirements;

and 3) senior managers did not have sufficient rationale to support securing an increase in manpower authorizations in a time of downsizing. Many of the sites that had succeeded in securing organizational GIS manpower had converted existing authorizations into GIS positions.

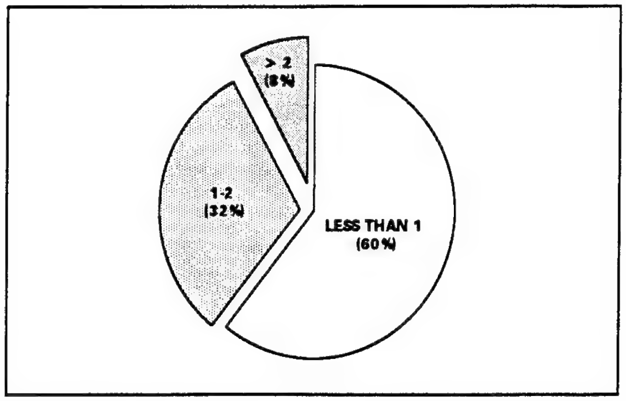

Figure 3-3. GIS Manpower Authorizations in Tri-Service Organizations

Pay Grades of GIS Managers. When federal organizations adopt new technologies, personnel issues such as job descriptions and appropriate pay grades can be difficult to assign since there are usually no precedents for their use. Figure 3-4 shows the pay grades for GIS managers ranged from GS-6 to GS-12, with GS-11 being the most frequently assigned. Readers should be reminded that most GIS managers had duties in addition to their GIS responsibilities. There was no apparent correlation between the scope of the implementation and the assigned pay grade. Several position descriptions were collected during the site visits and are available from the Center.

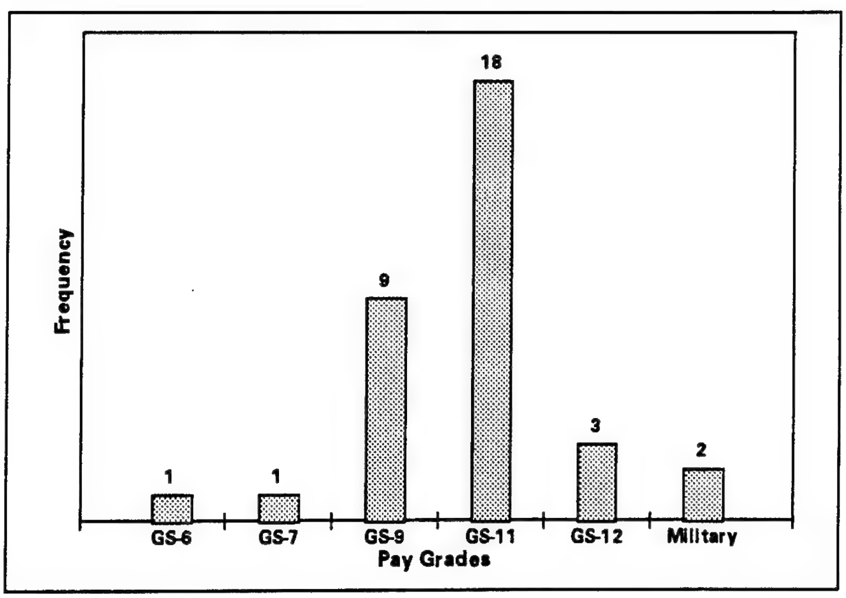

Figure 3-4. Frequency Histogram of GIS Manager Pay Grades

Establishment of GIS Objectives. Schultz, Slevin and Pinto (1987) derived a list of general factors they found to be crucial to the successful implementation of new information systems. First on the list of factors cited was the need to clearly define the goals of the system and to secure a commitment to those goals from key members earmarked to use the system. Figure 3-5 shows that almost two-thirds of the adopting organizations reported they had not formally specified or objectives for their GIS programs.

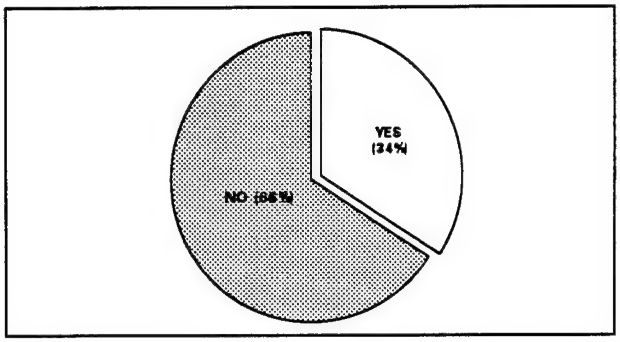

Figure 3-5. Installations Stating Specific Objectives for GIS

Development of Formal Implementation Plans. Figure 3-6 shows there were few organizations with formal GIS implementation plans. Many organizations felt they had an "informal" plan which usually implied there was nothing "written down", while others shared their frank opinions that formal plans only served to restrict their options in managing a fast-moving technology. The USACE Civil Engineering Research Laboratories (CERL) staff had published an informative guide for implementing GRASS on US Army installations but the organizations lacked the resources to comply with the document.

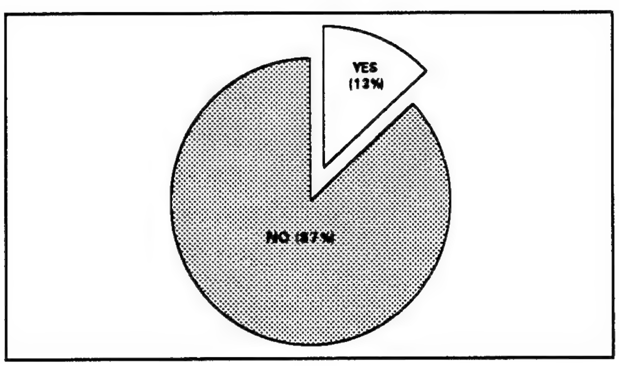

Figure 3-6. Organizations with Formal Implementation Plans

Mechanisms for GIS Implementation. Almost two-thirds of the implementations were being accomplished by a single individual. The US Army's GRASS support staff at CERL conducted implementations at almost one-fourth of the surveyed sites. The remaining organizations had established either a committee with representatives from the organization's sections or there were formal inter-organizational committees with

representatives from across an installation. For example, Edwards AFB had established an inter-organizational steering committee headed by the deputy installation commander.

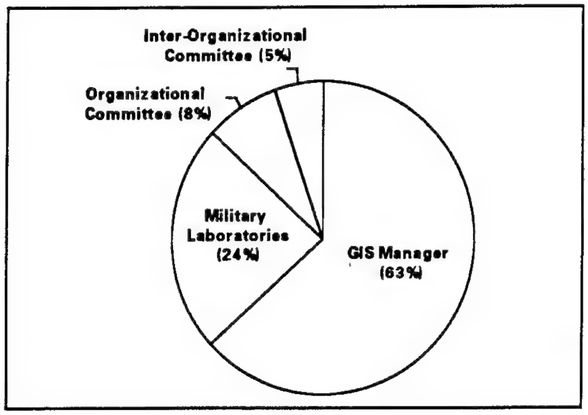

Figure 3-7. Mechanisms Used for Tri-Service GIS Implementation

Existence of Metadata Files and Spatial Data Dictionaries. Organizational instability can doom a GIS since frequent personnel turnover causes much of the corporate knowledge to be lost unless tools such as data dictionaries and metadata can help ensure continuity. Figure 3-8 shows a majority of sites had neither and were thus very susceptible to both misuse and abandonment of their database investment. A few sites were attempting to use the earliest versions of the Tri-Services Spatial Data Standards while others were using a variety of informal means to accomplish the two noted tasks.

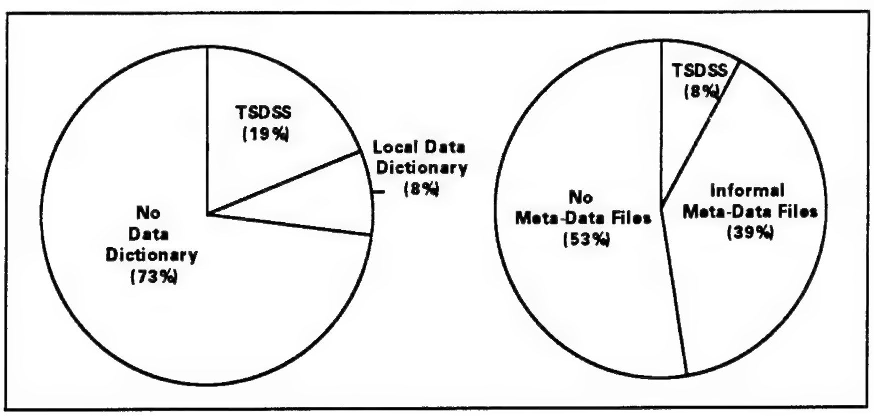

Figure 3-8. Organizational Use of Data Dictionaries and Metadata Files

Strategies for Evaluating GIS Performance. GIS implementations can benefit from occasional program evaluation during their development. Unfortunately, most sites had neither formal plans nor system objectives to evaluate (see Figures 3-5 and 3-6). Therefore, it was not surprising to find few sites with a strategy for assessing their GIS implementation progress (Figure 3-9). This lack of strategies for GIS evaluation did not necessarily imply apathy on the part of the field members. Instead, most of the GIS managers were eager to conduct such assessments, but were not aware of the required tools or methods.

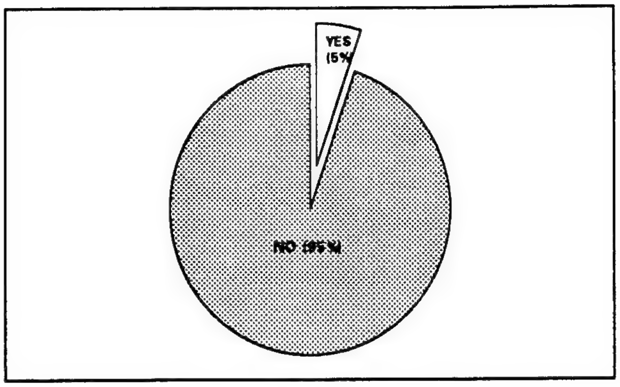

Figure 3-9. Surveyed Organizations with GIS Assessment Strategies

Extent of GIS Induced Organizational Changes. The adoption of advanced information technologies usually requires changes in the organizational and human resource practices to achieve real performance gains. Subsequently, GIS adoption can represent a serious "threat to the status quo of many organizations" (Obermeyer and Pinto, 1994). Senior managers were asked in their personal interviews whether their organization had experienced any notable structural, administrative or other changes as a result of the GIS adoption. Over half of the adopting organizations could recall no changes attributable to the GIS adoption decision as of the survey date (Figure 3-10). This trend suggests that military installations were maintaining the status quo. The principal investigator, however, was left with the definite impression that this lack of operational change was partly due to these managers being unaware of what changes *needed* to occur. An aggressive evaluation program would help provide this information.

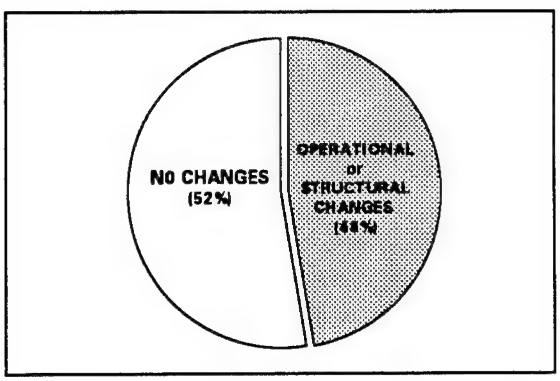

Figure 3-10. Extent of GIS-Induced Changes Among Surveyed Organizations

4 Management Responses to GIS Adoption

The site visits allowed the principal investigator to personally interview senior managers who carried oversight responsibility for the GIS investment. These individuals were asked a series of open-ended questions and then they also completed a short quantitative survey to more accurately assess their opinions on key adoption issues.

Managers of the organizational GIS were also asked open-ended questions that focused on the implementation process. They too completed the same quantitative survey as their senior managers. This dual, independent survey allowed five different opinion comparisons to be made between the GIS managers and their respective superiors regarding the outcome to date of their GIS implementation. Appendix B lists all the interview questions and surveys presented to these two groups.

Surveys of both the senior and GIS managers could not be accomplished at eight of the installations. At three of these sites, there were no senior managers who were aware of the GIS investment to the extent they could provide informed opinions. Senior managers at another three of the sites were not available due to mission requirements. The GIS manager at one site elected to not participate in the survey. Finally, since Pine Bluff Arsenal was using an off-site manager, they also were not included in this analysis.

To provide some structure to the discussion, the responses to the unique questions posed to each group will be presented first. The results of the comparisons of opinions on five key issues gathered from the formal survey will conclude the chapter.

Interview Questions Unique to GIS Managers

Perceived Level of GIS Policy Guidance from Higher Headquarters. When new programs are instituted at the field level, managers look for policies issued by higher authorities to help guide their implementation. The rapid development and diffusion of GIS, however, was much faster than the ability of senior service echelons to compile and distribute such guidance. All but one of the sites responded there was virtually no GIS policy provided to the field. This fact underscores the need to impart greater spatial technology awareness to the senior policymakers so they can better oversee effective implementations.

Technical Competence of GIS Managers. A component necessary for effective GIS management is having the necessary technical skills (Obermeyer and Pinto, 1994). The goal of successful GIS adoption at an installation should carry an implied goal of local personnel becoming largely independent from having to always rely on costly outside technical support. Therefore, GIS managers were asked to describe to what degree they currently relied on outside technical expertise to make effective use of their GIS. One-fourth described their sites as either totally or mostly independent from outside support. Another 12% of the managers said they only needed technical support infrequently for

extraordinary GIS operations. The remaining two-thirds described their use of outside technical support as either very frequent or one of complete dependence to accomplish their GIS tasks. Those sites requiring the greatest technical assistance were usually lacking a full-time GIS manager and were attempting to use software fielded on UNIX-based workstations.

Interview Questions Unique to Senior Managers

Funding Sources for Tri-Service GIS Programs. All bureaucracies seem to share a common burden of having to decide how their decreasing budgets are allocated across a seemingly ever increasing mission workload. An indicator of the degree to which GIS had been accepted as an integral organizational component was the extent to which fiscal resources were dedicated to its sustainment in a recurring manner. Unless an organization had some fiscal 'slack' or uncommitted fiscal resources, a GIS program would likely not receive sustained funding unless a significant causal relationship had been established between the GIS and critical mission elements.

Senior managers were asked to describe the primary funding source used to develop the GIS capability. Several different means were being used to pay for GIS programs even within the same service. Most senior managers had the latitude to obligate their available fiscal resources in support of GIS under the umbrella of a broad mission goal such as environmental restoration. Non-recurring fiscal resources such as LEGACY or DERA grants as well as end of year slack had also served to date as primary means of GIS funding. Those organizations best able to secure multi-year GIS funding had large environmental missions and mandates that could only be satisfied with the aid of a GIS. None of the senior managers were aware of any service-wide programmatic GIS support being considered.

Defining GIS Implementation Success. Successful GIS implementation can only be achieved if an organization has decided what constitutes "success". To help in identifying a consensus definition of desired implementation outcomes, senior managers were asked to define GIS implementation success in their own words. Their responses were recorded and are presented below:

"When better scientifically-based decisions can be made using robust, current data capable of recording cumulative impacts rather than an "off-the-cuff" qualitative assessment which are made now."

"When all the capabilities of the equipment are being used, GIS information and products are integrated into the decision-making process, all users who need GIS feel comfortable accessing the system, and an individual has direct access to GIS staff for assistance."

"When the GIS is routinely used to provide a product"

"Trained users are aware of the potential applications, have the data they need available in the system, and they make use of the system."

“A GIS is successful if it is used by the organization.”

“A system that will help us make more informed land management decisions.”

“A customer can receive an accurate, up-to-date product with a simple request.”

“GIS implementation success is achieved by providing one-stop shopping for the military trainer who wants to know how to conduct their operations without conflicting with environmental management policies.”

“The GIS must be integrated into the bottom-up process. If a new technology is forced top-down through stovepipes, regardless of how many "torch carriers" there are, the technology will die off. The perfect analogy is TQM; ask the mechanic on the flightline what TQM means to them.”

“Achieving a degree of operational readiness that is being actively used. Not so much products, but the extent of use after individuals have received training.”

“All potential users of spatial data are capable of making easy, casual use of the technology with minimal training.”

“Easy data flow into the system accessible by project engineers and not just the GIS operators.”

“The timely provision of products to help with engineering and environmental decisions.”

“A successful GIS is perceived as truly helping to protect natural resources in the opinions of the users.”

“All members of the Environmental Management Division using spatial data being able to access the GIS data and perform their jobs in a more efficient and effective manner.”

“Having people use the system to assist in making better environmental management decisions.”

“All people with spatial data needs being able to access a system containing useful information to assist with environmental management.”

“A GIS implementation is successful if it has been completely interwoven into all facets of compliance.”

“A successful GIS implementation is achieved if the people are using it in their jobs.”

“A GIS implementation is successful if there are dedicated GIS organizational personnel who can produce knowledgeable products.”

“An implementation is successful if the GIS can answer questions asked of it.”

"The success of a GIS should be measured in different ways: 1) How happy are those people who are using the system to do their job; 2) What increases in job performance efficiencies have been recorded; and 3) What is the extent of GIS use throughout the organization from manager to technician."

"This is very difficult since it is such a subjective process. I believe the success of a GIS program can be measured through the efficiencies gained by using GIS for mapping of various scales and scopes in a timely manner. There is value in knowing the information can be retrieved readily and the cost-effectiveness can be demonstrated."

"A system that is used and also generates products that are useful."

"Is the system being used? [The Division Chief] was getting a lot of heat since the GIS was an economic black hole with no products. Finally, now, [the Division Chief] asked [the GIS Program Manager] for a map of cemeteries on the base and he was able to provide it quickly. Success!"

"A consolidation of good data manipulated to produce useful products for people to easily acquire in support of their mission tasks."

"A system meeting mission needs at reasonable cost."

"When the implemented software is 1) perceived as user friendly; 2) contains accurate data; and 3) has been integrated into the mission."

"The ability to use the system to support environmental decision making and meet multiple demands."

Cowen (1988) describes multiple approaches to defining a GIS and most of these were touched upon in the responses of the senior managers. For instance, some viewed the GIS as a quality database to be exploited, while others only viewed the GIS in terms of tangible products to assist with recurring decisions. Still others looked at the process of individuals using the data and being able to feel satisfied they had accomplished better decisions through system use. The general consensus was that if the intended users are actually making use of the system and the technology is supporting operational decision making, the implementation can be considered successful. These responses provide an initial point of departure in securing a widely accepted dependent variable for studying future GIS adoption outcomes across tri-service installations.

Interview Questions Common to Both Senior and GIS Program Managers

Perceived Obstacles to Organizational GIS Success. Senior and GIS managers were asked to identify two issues they considered to be the most serious obstacles inhibiting their successful implementation of GIS. Recall that their responses were gained during independent and private interviews. Table 4-1 lists their responses prioritized by frequency.

Table 4-1. Obstacles to Achieving Organizational GIS Success		
Senior Management Perceptions		GIS Management Perceptions
Ranking	Issue	Issue
#1	Need for Education Management Awareness HHQ Awareness User Training Implementation Awareness Length of Implementation	Need for Education Applications awareness Management Support User Training Implementation Awareness Length of Implementation
#2	Need for Manpower Stability Acquiring Manpower Authorizations	Need for Manpower Stability
#3	Need for Funding Stability	Need for Funding Stability
#4	Resolving Technical Issues Installation of Networks Reducing Software Complexity Securing Adequate Technical Support	Resolving Technical Issues Improved Output Capability Reducing Software Complexity Securing Technical Support
#5	Coping with Information Politics Resistance to Change Control of Information Tri-Service Cooperation	Coping with Information Politics Control of Information Resistance to Change
#6	Need for Improved Data Quality	

Both groups perceived the lack of awareness as the most serious inhibitor. The consequences of this lack of awareness is pervasive in all of the trends noted thus far. Both echelons also agree the second and third most serious issues were the instability of both the manpower and fiscal resources. It is difficult enough to implement a new technology within an organization without having to additionally cope with decreasing human and fiscal resources. Only after citing their organizational/institutional concerns did the technical issues surface. This underscores the fact that technical issues are less of an impediment to an implementation than those obstacles posed by more social issues (Onsrud and Pinto, 1992).

Suggested Role of the Tri-Services CADD/GIS Technology Center. The Center's greatest challenge may lie in securing a consensus opinion from the tri-services about the specific role the Center can fulfill in facilitating CADD/GIS success. To help in this mission clarification, the principal investigator asked both groups to suggest some implementation needs the Center could possibly address. Table 4-2 lists their responses prioritized by frequency.

All of the suggested Center roles from both groups reflected the field's need for gaining enhanced awareness; awareness not only of other GIS programs, but also greater knowledge of the technology's potential and the specific implementation steps necessary to realize this potential and ensure their sustainment .

Table 4-2. Suggested Center Role			
Senior Management Perceptions		GIS Management Perceptions	
Ranking	Role	Ranking	Role
#1	Serve as a tri-service clearinghouse for issues relevant to GIS adoption	#1	Serve as a tri-service clearinghouse for issues relevant to GIS adoption
#2	Enhance levels of GIS awareness among senior tri-service and installation officials	#2	Provide technical support for GIS program development
#3	Enhance awareness of potential applications for GIS technology at military installations	#3	Enhance awareness of potential applications for GIS technology at military installations
#4	Provide general assistance with GIS implementation tasks	#4	Enhance levels of GIS awareness among supervisors and senior installation officials
#5	Stay in touch with the implementation needs of the installations	#5	Promulgate spatial data standards
#6	Provide technical support for GIS . program development	#6 (Tied)	Provide systems administration training Disseminate staffing standards Assist with hardware /software acquisition Provide general implementation assistance

Comparing Management Opinions of Key Implementation Issues

This final section will present the findings of a comparative analysis of the quantitative surveys administered to the senior managers and their respective GIS managers. Five key issues were explored; perceived overall satisfaction with the organizational GIS; perceived satisfaction with the return on the organizational GIS investment; perceived level of integration of the GIS into organizational standard operating procedures; the perceived need to provide evidence of the cost-effectiveness of GIS to ensure continued funding; and the perceived need to develop a strategy for evaluating the GIS performance. Organizational responses were paired and then all the pairs were subjected to a statistical test ('t' test) which determined whether the average responses of the two groups were significantly different.

Perceived Satisfaction With the Organizational GIS Program.

Original Hypothesis: Senior managers and GIS managers perceived the same level of general satisfaction with their organizational GIS.

Test: A series of 8 questions each with a 7-point range were presented to each respondent. There were 30 pairs of management opinion data.

Discussion of Results: The original hypothesis could *not* be rejected. Both management groups shared a common perception of relative 'lukewarm' satisfaction with their GIS program (Figure 4-1). Statistically significant differences would have suggested these groups held differing perceptions of the impact of GIS on the organization.

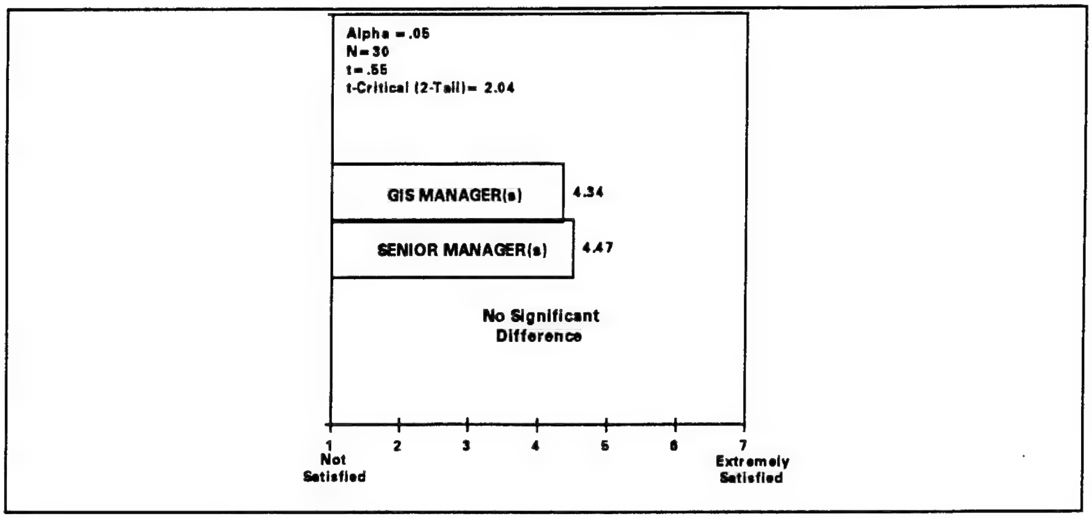

Figure 4-1. Comparison of 'Satisfaction with GIS'

Perceived Satisfaction with the Economic Return on the GIS Investment.

Original Hypothesis: Senior managers and GIS managers were equally satisfied with the perceived economic returns on their GIS investment.

Test: Each respondent was asked to state the degree to which they were currently satisfied with the return on their organization's GIS investment. A 7-point scale was used to record their responses.

Discussion of Results: Senior managers and GIS managers did *not* feel the same level of satisfaction with the return on their GIS investment. Senior managers recorded a significantly *higher* level of satisfaction with the return on their GIS investment than the GIS managers (Figure 4-2). Since senior managers were more distant from the day-to-day operations of the GIS program, GIS managers were likely to be more cognizant of the *real* system benefits and costs. In simpler terms, those who know less of the technology's true potential would tend to report greater overall satisfaction with any output presented. For this and other reasons, Ginzberg (1981) suggests that when program evaluations are being developed, such inflation can be avoided by having only those personnel who played an active role during initial system definition providing the benchmark expectations.

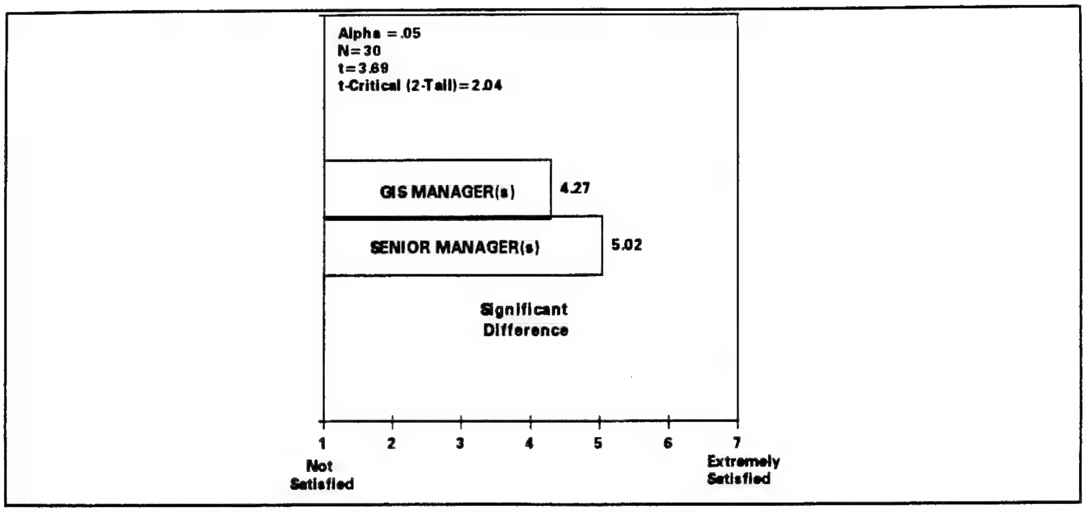

Figure 4-2. Comparison of 'Satisfaction with Perceived Return on GIS Investment'

Perceived Integration of the GIS into the Organizational Mission.

Original Hypothesis: Senior managers and GIS managers perceived the GIS to have been integrated into the organizational mission to the same extent.

Test: Respondents were asked to state the degree to which they felt the GIS has been made a long term, integral part of the organization. A 7-point scale was used to record their responses.

Discussion of Results: The original hypothesis could *not* be rejected. No discernible differences were found between the perceptions of senior managers and their GIS managers toward the extent of GIS integration into the organizational mission. The response was still only 'lukewarm' indicating a good deal of work still had to be done before the GIS could be considered an integral mission element.

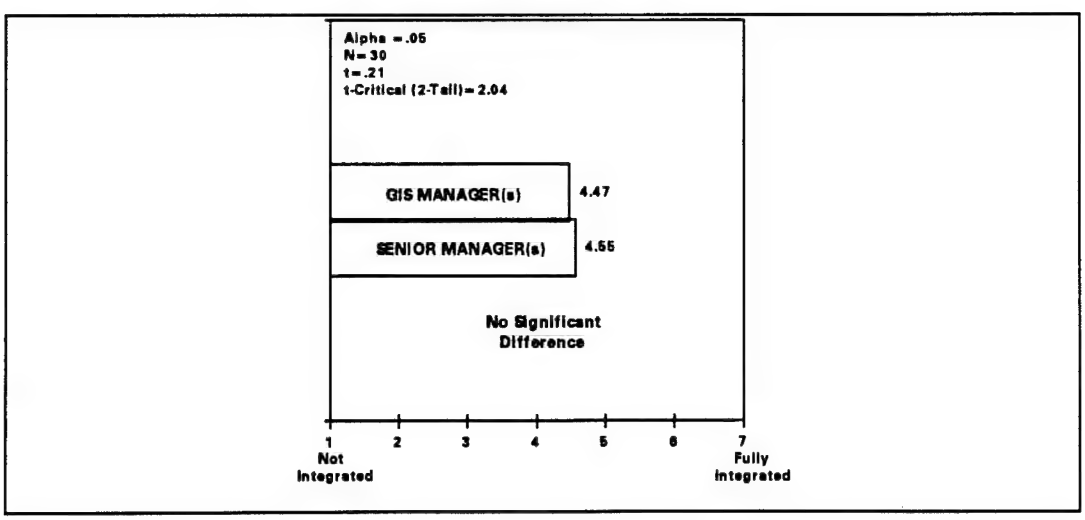

Figure 4-3. Comparison of 'Perceived Level of GIS-Mission Integration'

Perceived Need for Demonstrating the Cost Effectiveness of GIS.

Original Hypothesis: Senior managers and GIS managers perceived the need to acquire evidence of the cost effectiveness of GIS as equally important to securing continued funding of the program.

Test: Respondents were asked to state the degree to which they felt it was important to the continued budget support of GIS for them to see tangible evidence of the cost-effectiveness of using GIS technology. A 7-point scale was used to measure responses.

Discussion of Results: The original hypothesis could *not* be rejected. Both senior managers and GIS program managers shared the view it was *very* important to provide more tangible evidence of the GIS cost effectiveness. When the novelty of an innovation begins to wane and previous expenditures have yet to produce apparent gains in operational efficiencies, it would be prudent for senior managers to question future outlays. Greater attention needs to be given to developing more rigorous means of assisting organizations with post-implementation GIS benefit-cost accounting.

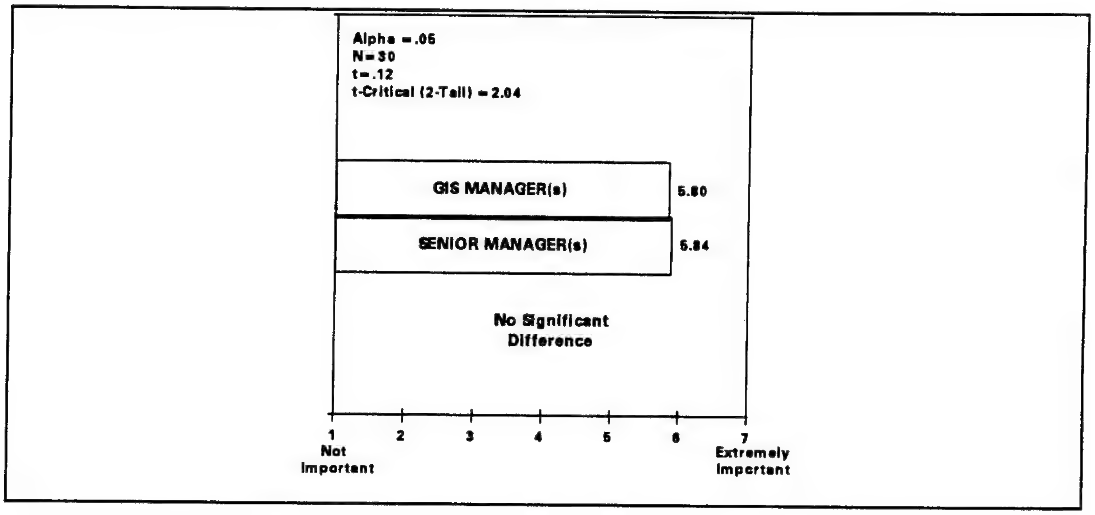

Figure 4-4. Comparison of the 'Importance of Gaining Evidence of Cost Effectiveness'

Perceived Need for GIS Evaluation Strategy.

Original Hypothesis: Senior managers and GIS managers both perceived having a strategy for evaluating the performance of their GIS as equally important.

Test: Respondents were asked to state the degree to which they felt it was important to have a strategy for evaluating GIS performance. A 7-point scale was used.

Discussion of Results: The original hypothesis could *not* be rejected. This issue recorded the most extreme responses from both senior and GIS managers. They together felt it extremely important they have a means of being able to evaluate their GIS performance. This item does *not* necessarily imply the field is asking for a headquarters or Center

element to *conduct* the evaluation, just that a means be provided for installations to monitor their GIS program development.

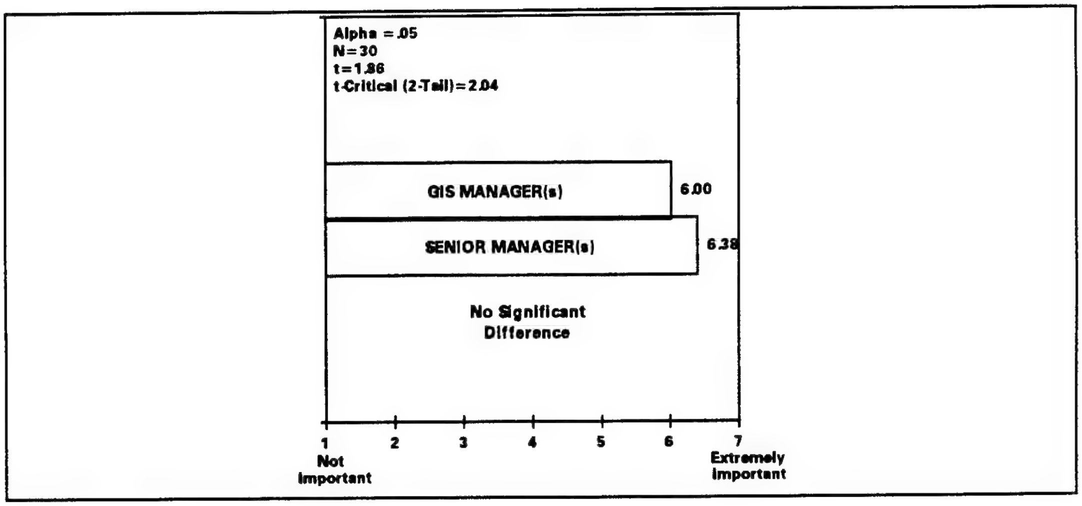

Figure 4-5. Comparison of 'Importance of Having a GIS Performance Evaluation Strategy'

5 Profiles of GIS Users

This chapter will profile those individuals at the surveyed installations who had been making actual direct "hands-on" GIS use. A GIS User Survey was personally administered to 82 individuals who were verified on-site by the principal investigator as being qualified to provide informed opinions on their GIS use experiences. A copy of the GIS User Survey is found in Appendix B.

Primary Organizational Duty Position. GIS users were asked to categorize their current duty responsibilities as either a GIS manager, GIS staff member, operations manager or operations support. Figure 5-1 shows the majority of GIS were those whose primary responsibilities involved the GIS program which suggests GIS is still in an early stage of diffusion.

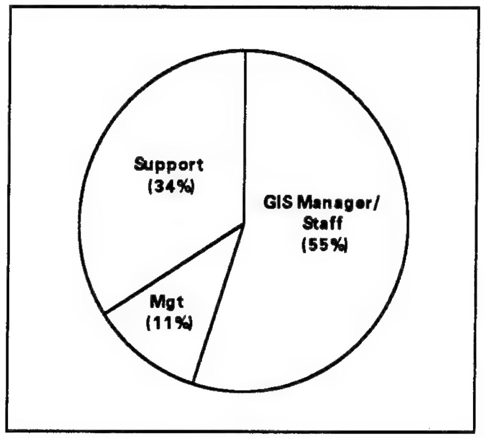

Figure 5-1. Primary Duty of GIS Direct Users at Surveyed Installations

Length of Federal Service. Figure 5-2 shows almost half of the direct GIS users were relatively new to the organization. This trend suggests most GIS users had been hired to assist with the GIS program.

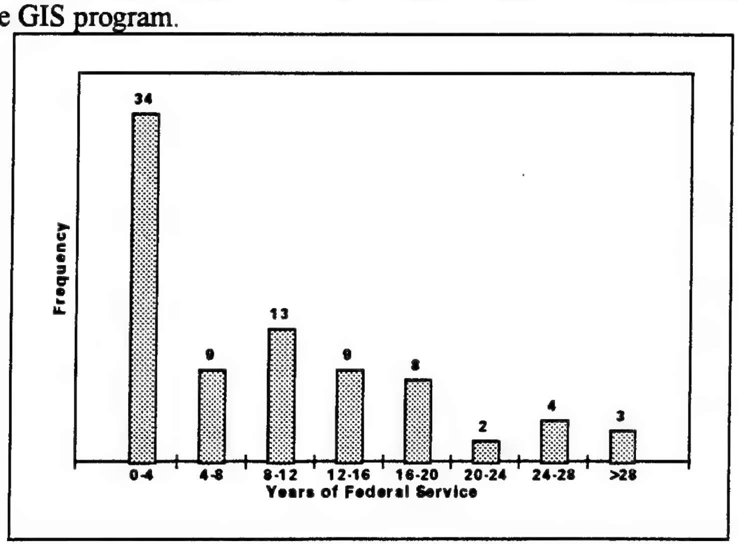

Figure 5-2. Frequency Histogram of Years of Federal Service of Direct GIS Users

Extent of GIS Experience in Non-Federal Sectors. Survey respondents were asked to describe their previous GIS experiences (to include formal education) prior to moving to the federal workforce. Figure 5-3 indicates that 8 out of 10 GIS users came to the federal workforce with no prior GIS experience. This trend suggests the tri-services should give increased emphasis to examining the training opportunities afforded to intended GIS users since few come to the organization 'GIS-equipped'.

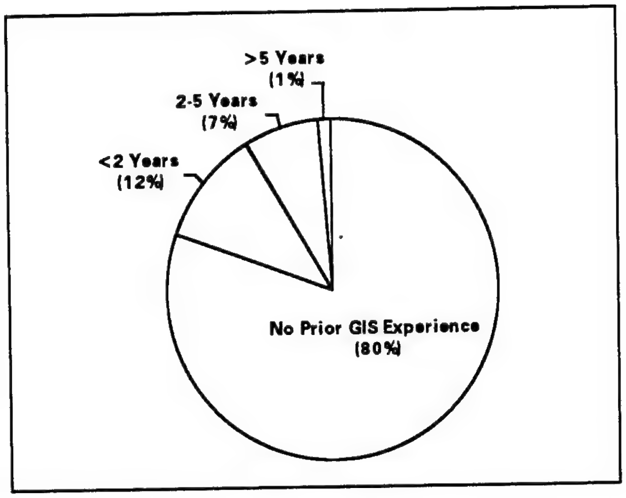

Figure 5-3. Years of Non-Federal GIS Experience of Direct GIS Users

Length of Personal Use of the GIS. GIS users were asked to report how long they had been making use of organizational GIS resources. Figure 5-4 shows the skewed distribution that had a median of almost two years of direct GIS use.

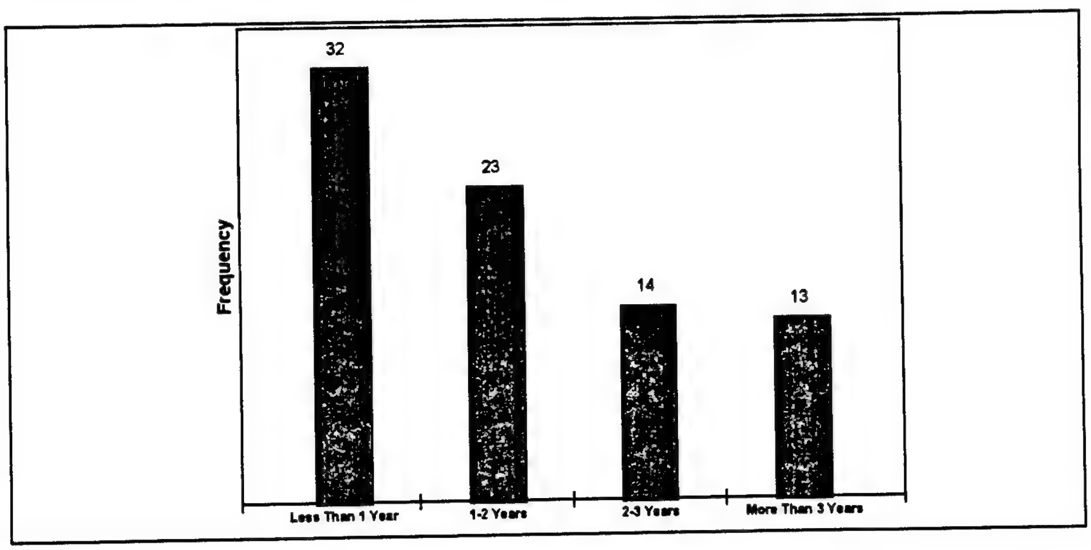

Figure 5-4. Frequency Histogram of the GIS Use Experience of Direct Users

Percentage of GIS Work Performed for Indirect Users. Given the relative youth of many programs and the minority of direct use being made by non-GIS staff members, it was likely most of the direct GIS use was being conducted for others (GIS "chauffeuring"). Direct GIS users were asked to describe what percentage of their GIS

use was being accomplished in support of other's expressed need for spatial data products. The responses indicated almost half of all direct GIS work performed was in support of requests from other non-GIS users in the organization.

Extent of CADD Experience. CADD technologies have been present and used extensively on military installations for a long time, with almost exclusive use being made by those responsible for infrastructure design, development and maintenance. Advances in CADD/GIS integration offers an opportunity for experienced CADD users to enhance their applications with new analytical capabilities. GIS users were asked to describe the extent of their previous CADD experience. Figure 5-5 finds most GIS users had no previous CADD experience and only a small fraction had more than five years of CADD experience. As more of the integrated CADD/GIS solutions for installations are implemented, this graphic will certainly reflect a growing number of previous CADD users broadening their analytical tasks to include GIS operations.

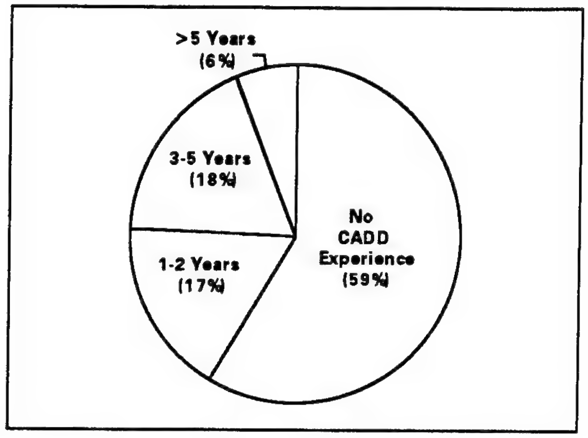

Figure 5-5. Years of CADD Experience of Direct GIS Users

Computer Experience Prior to Using the GIS. Early GIS adopters would likely already feel relatively comfortable with computers. Figure 5-6 shows more than 90% of the surveyed GIS users had a reasonable amount of computer experience prior to their adoption of GIS.

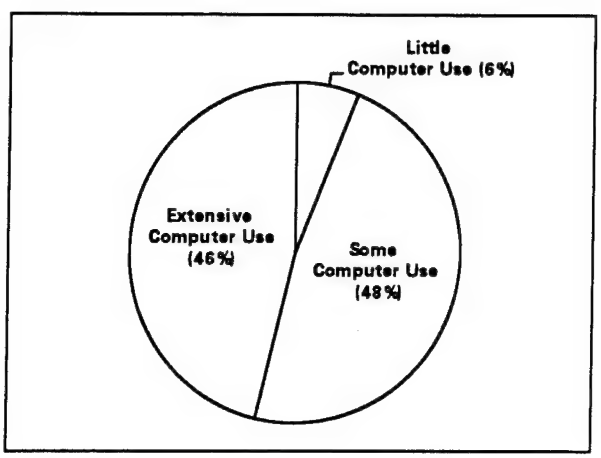

Figure 5-6. Extent of Computer Use Prior to GIS Use

Direct User Satisfaction With the Organizational GIS. One of the two most common means of assessing adoption responses to new information technology is user satisfaction (Igbaria and Nachman, 1990). Figure 5-7 shows a majority of current GIS users felt very satisfied with their organizational GIS according to the satisfaction scale found in Part III of the GIS User Survey. The categorical descriptions were derived by trisecting the average responses to the 8-item satisfaction scale.

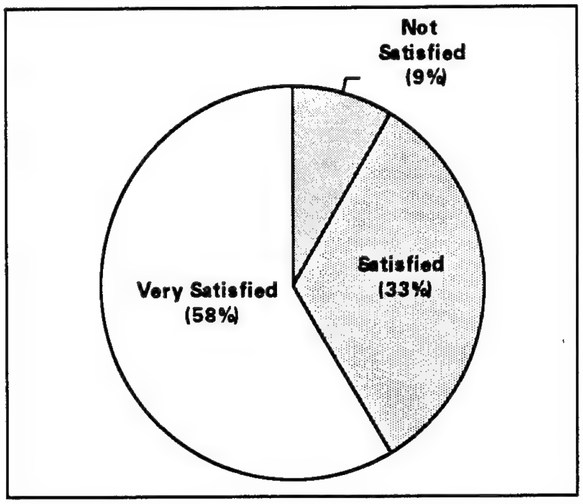

Figure 5-7. Degree of Direct GIS User Satisfaction

Extent of Direct GIS Use. A second means of assessing adoption responses is the extent of system use. Delone and McLean (1992) recommend at least two measures be used to assess the construct of adoption outcomes. Figure 5-8 shows 30 users reported using the system more than once every day, but there was an almost equal number that reported system use of about once a week or less (25). Since these two groups constitute two-thirds of the total surveyed, it would suggest a bi-model distribution tending towards full-time and part-time or casual users.

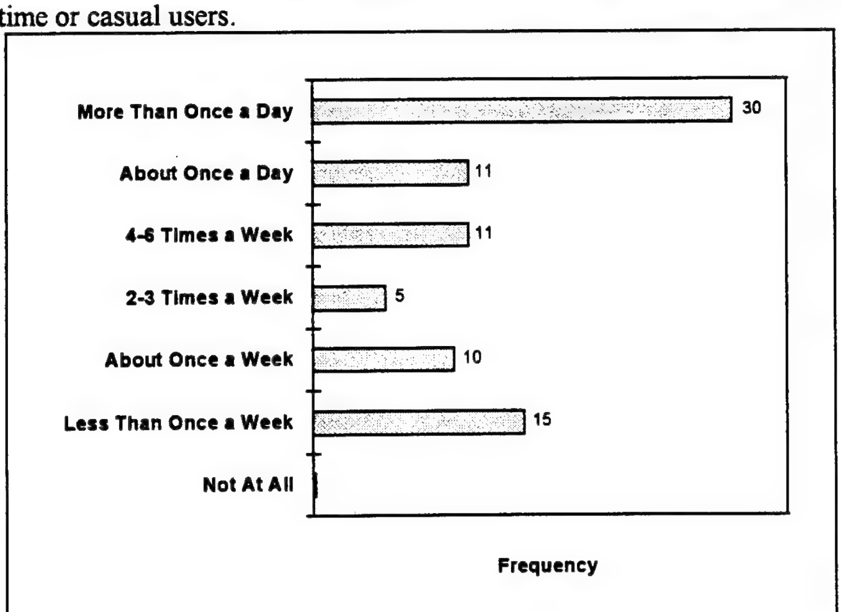

Figure 5-8. Frequency Histogram of Direct Users by Extent of their GIS Use

Comparing Adoption Responses of GIS Staff With Other GIS Users. Direct GIS users were classified into two sub-groups; those with a primary GIS responsibility (GIS managers and their staffs) and those who had other mission support responsibilities (both managers and technicians). The first item on the GIS User Survey permitted this nominal categorization and subsequent comparison of their implementation behavior. Two items of specific research interest were the comparative degrees of satisfaction and extent of use.

An individual's current GIS satisfaction would likely be influenced by different issues. For example, an individual who had primary responsibility for developing the GIS would likely use the system more than someone who had other primary responsibilities. As an individual made more use of the GIS, they would likely gain increased satisfaction with the GIS as they acquired greater abilities to exploit the GIS. On the other hand, those who were not able to use the system as frequently would likely ascend this GIS confidence/satisfaction curve less quickly. This hypothesis can be tested using a two-sample t-test.

Original Hypothesis: GIS managers (and their staffs) are just as satisfied with the GIS as those direct users who fill other organizational management and support roles.

Alternative Hypothesis: GIS managers (and their staffs) are significantly more satisfied with the GIS as those direct users who fill other organizational management and support roles.

Test: Two-sample t-test assuming unequal variances (Barber, 1988).

Discussion of Results: Reject the original hypothesis and accept the alternative hypothesis. GIS managers and their staffs recorded a significantly higher level of satisfaction than other organizational GIS users (Figure 5-9). A more specific model examining the relationship of adoption success to various influences such as ease of system use will be addressed in the next chapter.

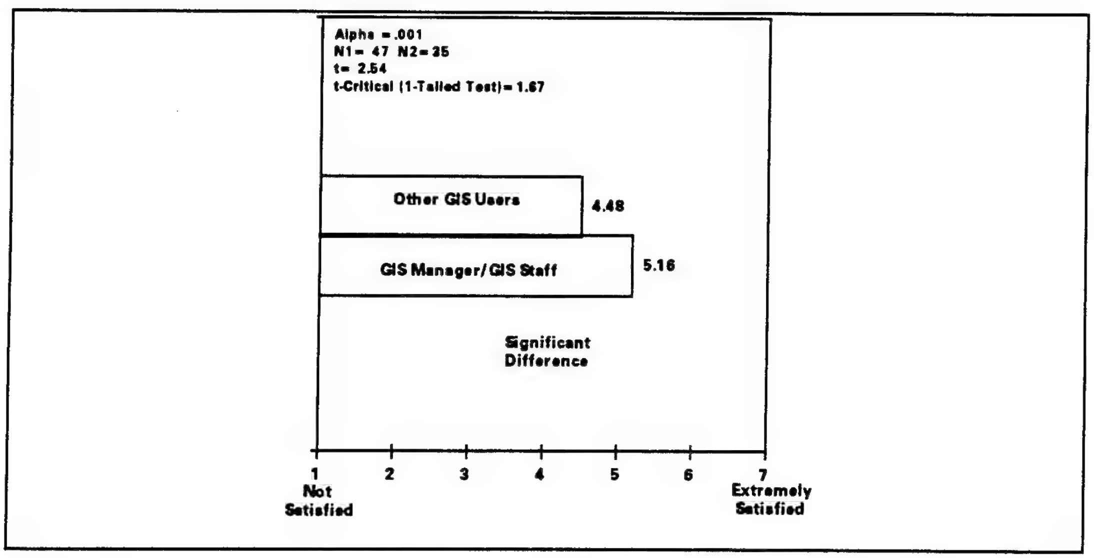

Figure 5-9. Comparison of GIS Satisfaction Between GIS Staff and Other Users

The extent of GIS use in an organization would be influenced, in part, by the relative maturity of the GIS development. Since the trends have described an early stage of GIS development, those outside of the core GIS development staff would probably not yet have access to a wide array of GIS applications specific to their job requirements. Therefore, GIS users who were not full-time GIS staffers were probably using the GIS less due to their lack of tailored applications. This hypothesis can be tested using the same t-statistic.

Original Hypothesis: GIS managers and their staffs used the GIS to the same extent as those direct users who fill other organizational management and support roles.

Alternative Hypothesis: GIS Managers and their staff used the GIS to a significantly greater extent than those direct users who fill other organizational management and support roles.

Test: Two-sample t-test assuming unequal variances (Barber, 1988). A 7-point scale was used to measure responses.

Discussion of Results: Reject the original hypothesis and accept the alternative hypothesis. There was a significant difference in the extent of GIS use between the two groups of direct users (Figure 5-10). As tailored applications for non-GIS staff users are developed, there should be a narrowing of this 'use gap' between these two groups. The value of this metric again is entirely dependent on the organizational goal for the GIS implementation. Those organizations who elect to maintain a core of highly trained GIS professionals who perform all direct use of the system for others would find this of little value. However, those organizations who seek to have the widest possible number of direct GIS users would find this statistic more valuable.

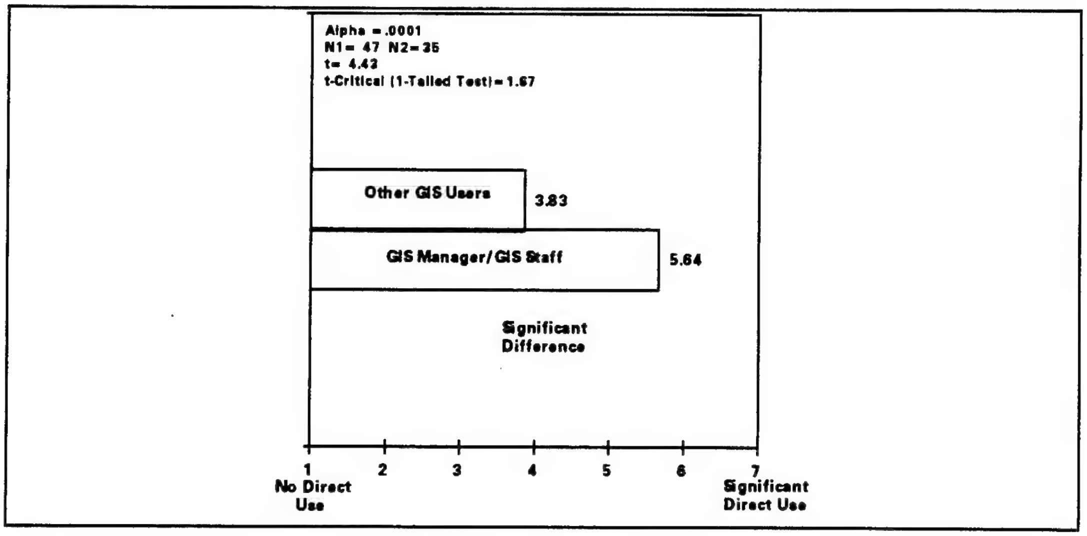

Figure 5-10. Comparison of GIS Use Extent Between GIS Program Staff and Other Users

6 Modeling Personal GIS Adoption Responses

A specific goal of the research was to identify those common influences affecting personal GIS adoption outcomes across the sample of surveyed organizations. This chapter will present the general research methods used to accomplish this task. A more detailed, academic discussion of this modeling phase of the research can be found in the dissertation compiled by the principal investigator (Cullis, 1995). The statistical analyses performed are detailed in Appendix C of this report.

Influences Affecting Personal GIS Adoption Outcomes (Independent Variables)

The only precedent of a broad, scientifically-based survey of GIS adoption responses was performed by Onsrud and Pinto (1992). Their survey asked GIS managers for their opinions of how important 34 social and technical issues were the current success of their organizational GIS programs. The relatively poor performance of their models led the authors to suggest further adoption research needed to include a wider number of possible influences affecting the outcome of GIS adoption.

An initial set of influences to include in a survey of users was compiled during the Fall 1993 phone survey. Senior and GIS managers were asked for three key influences they felt were significant facilitators or inhibitors to their GIS use. These responses were combined with those influences discovered through an extensive search of previously published accounts of information systems adoption research. A final set of 52 social and technical influences possibly affecting GIS adoption on military installations were included in the GIS User Survey found in Appendix B.

Since the goal was to assess how much a given issue (e.g. degree of top management support) either negatively or positively influenced the individual's use of their GIS, a bi-polar Likert-type scale was used to capture the degree of influence away from a neutral midpoint or region of no influence. Given the unknown direction of the influence in any organizational setting, a five-point scale in either direction was employed resulting in an overall nine-point integer scale ranging from -4 to +4. End points were labeled "Extremely Negative" and "Extremely Positive". The mid-point value of '0', implying the given item has no influence on their use, was printed in smaller case relative to the other numbers since suggestion of a neutral alternative usually encouraged selection as an easy answer (Sheatsley, 1983).

Defining the Adoption Outcomes (Dependent Variables)

With the possible influences affecting GIS outcomes identified, it was necessary to strictly define the dependent variables or adoption outcomes to be used in the model. Galletta and Lederer (1989) portrayed information system implementation outcomes as having two dimensions; economic and personal. The GIS research community has devoted

significant effort to better modeling the economic outcome of GIS implementation (e.g. Dickinson and Calkins, 1988; NCGIA, 1989; Gillespie, 1992). However, while a system may have great potential to contribute to organizational performance, benefits will only be achieved through actual system *use*.

The credibility of any adoption success measure is bolstered by using more than just a single adoption outcome. Therefore, both the extent of system use and user satisfaction were selected to serve as the primary dependent variables defining individual GIS adoption outcomes. Over the past twenty years, these two outcomes have been the most popular means of assessing information system implementation success (Galletta and Lederer, 1989; Igbaria and Nachman, 1990).

Capturing Adoption Outcomes: Extent of GIS Use

Capturing the extent to which an individual makes use of the GIS required thoughtful consideration of just how this might take place. A model suggested by Swanton (1988) was adapted for this work and is found in Figure 6-1. This model assumes that personal use of an information may be of a direct "hands-on" nature or one of indirect or "chauffeured" use where this individual has another direct GIS user provide a GIS product for them. In sum, there could theoretically be at least three types of GIS users in an organization; direct users (DU), indirect users (IU) and those who make combined (direct and indirect) use of the GIS (CU). The model in Figure 6-1 effectively shows the complexities of accounting for total GIS use within an organization. It also graphically portrays how the diversity of personalities and the formal and informal roles and relationships within an organization lead each GIS user to adapt uniquely to the organizational GIS (Swanson, 1988).

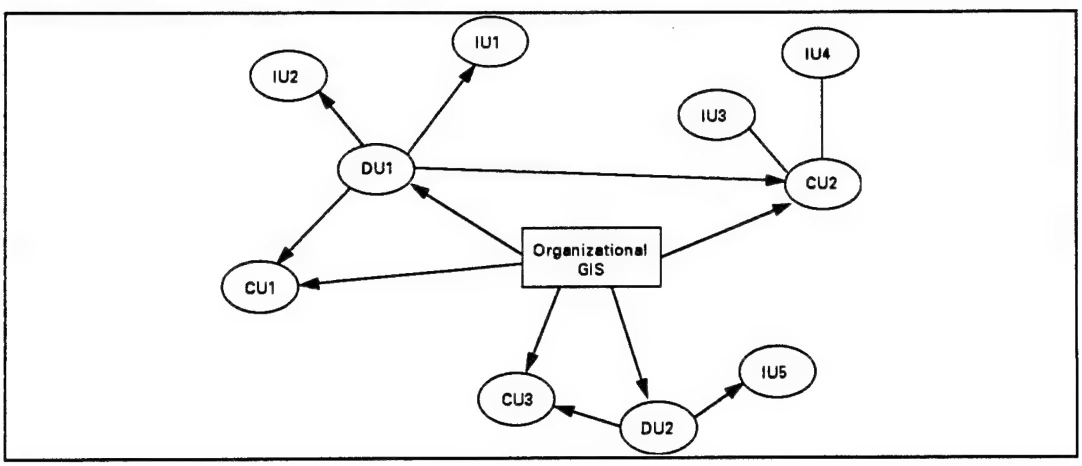

Figure 6-1. The Adaptive Interpersonal GIS Use Model
(After Swanson, 1988)

This research focused on the adoption responses of any individuals who made any *direct use* of the organizational GIS. Thus all those labeled as direct or combined users were identified in the surveyed organizations and administered the GIS User Survey. Direct *and* indirect GIS use were both measured using the same two-item construct. A

seven-point Likert scale was used with the adjectives “Frequently” and “Infrequently” at the endpoints. The second scale employed a 'check the box' format with categories for current use to include "Not at all", "Less than once a week", "About once a week", "2 or 3 times a week", "4 to 6 times a week", "About once a day", and "More than once a day". These constructs had been previously used by Davis et al (1989) in his Technology Acceptance Model were modified to measure the extent of personal GIS use.

Capturing Adoption Outcomes: GIS User Satisfaction

Information system user satisfaction can be defined as “the extent to which users believe their information systems meet their information requirements and contribute to organizational performance” (Ives et al, 1983; Sanders, 1984). The user satisfaction scale developed by Kim and Lee (1991) proved well-suited for surveying GIS adoption outcomes. The authors used multiple regression to test contingent relationships between various information system implementation strategies and their subsequent success among 57 business firms across six industries. This research defined a user’s GIS satisfaction as the extent to which an individual believed the GIS satisfied their information requirements and contributed to their organizational duty performance. Only slight modifications were made to the original scales used by Kim and Lee to adapt the survey items for assessing GIS user satisfaction. The final eight items comprising the user information satisfaction scale are found in Part III of the GIS User Survey in Appendix B.

The Populated Research Model

Once the GIS use influences were defined as well as the dependent variables, the general GIS research model was reassembled using a framework suggested by Ives et al (1980). Figure 6-2 shows how the 52 GIS adoption influences were grouped into 3 domains, all which help to describe the complex implementation process. There will be influences arising from both the external, organizational, development, operations and user *environments*. Some influences arise during the actual development and operations *process* of implementing the GIS. Finally, there can be more technical *GIS subsystem* issues influencing the extent to which a GIS is successfully adopted. These issues were certainly not going to account for all possible adoption outcomes, but they would serve as a valuable point of departure in identifying common factors affecting GIS adoption outcomes across military installations.

Figure 6-3 conceptually portrays how the GIS use influences and the adoption outcomes were modeled within the broader context of the innovation adoption process described earlier in Chapter 2. The individual GIS adopters were asked to report to what degree a total of 52 different social and technical influences had affected their personal outcomes to GIS adoption. These outcomes were measured in terms of the reported direct use, combined use and satisfaction with the GIS.

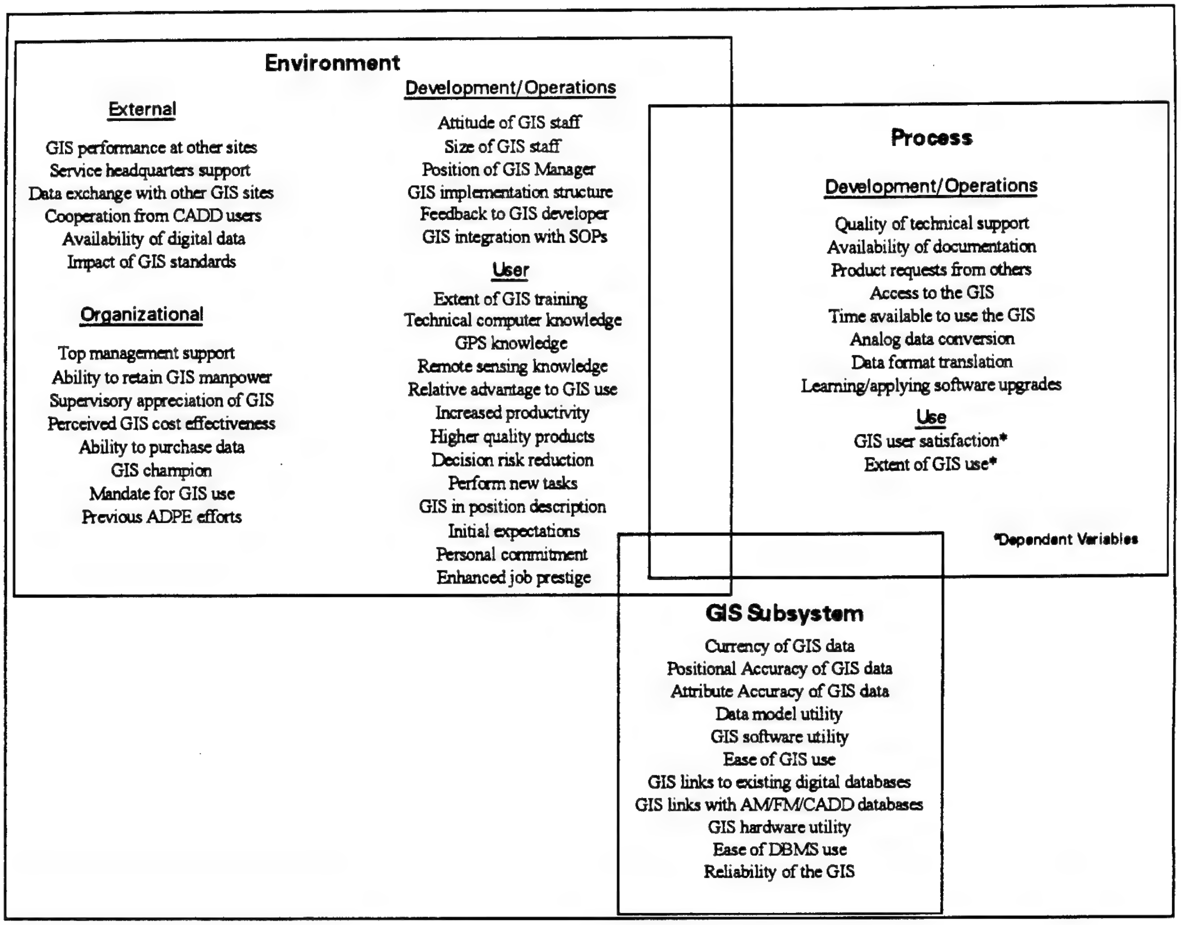

Figure 6-2. The Populated GIS Adoption Response Research Framework

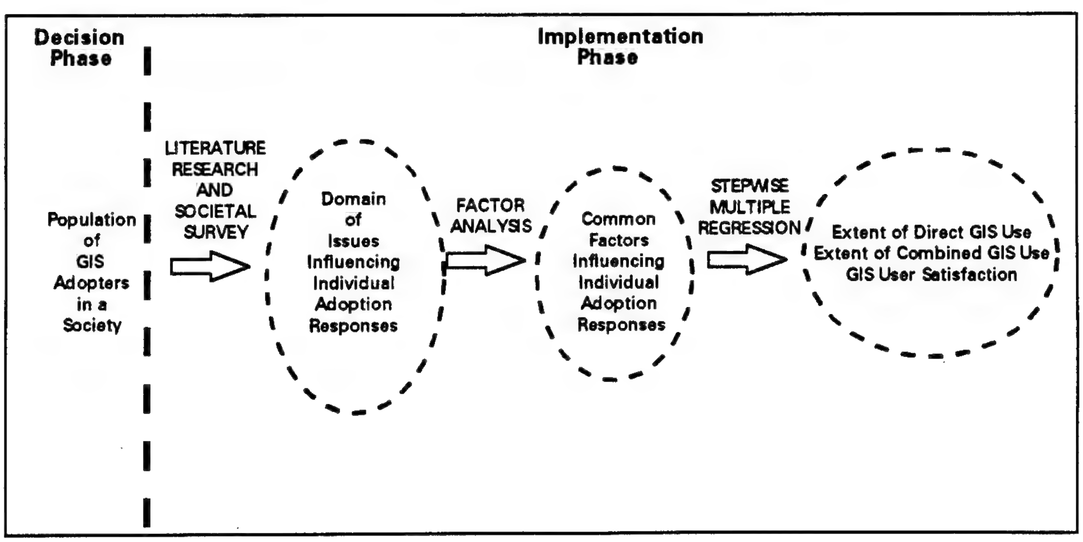

Figure 6-3. The Conceptual GIS Adoption Response Model

Instrument Pre-tests

The face and content validity of both the independent and dependent variable scales were pre-tested with key personnel involved in GIS research and development at the US Army Topographic Engineering Center, the Air Force Center for Environmental Excellence, the US Army Corps of Engineers Cold Regions Remote Sensing and GIS Center, and the US Army Corps of Engineers Civil Engineering Research Laboratories. Minor adjustments were made to various survey components based on their feedback.

The Number of GIS User Survey Respondents

During the Fall 1993 phone surveys, GIS managers had reported a total of 180 personnel had the trained capacity to make direct use of the GIS. However, when the installations were visited, only 82 total direct GIS users were found with a median of two per organization. Three reasons contributed to this discrepancy; 1) GIS managers were not fully aware of the extent to which those who had received training had abandoned attempting to personally use the GIS; 2) GIS managers exhibited the common tendency to over-report program success; and 3) those individuals who had abandoned use of the GIS could not accurately recall specific influences leading to their discontinuance and thus had to be excluded from this survey.

Factor Analysis of the GIS Adoption Influences

Within a large body of social and technical influences affecting GIS adoption outcomes, there are likely to be a smaller group of latent or hidden factors underlying the response patterns. An example would be the perceived degree of organizational support for the GIS implementation. Such a perception would be formed by an individual user's perceptions of several issues such as a willingness of the organization to purchase system components, supervisory attitudes towards allowing individuals to use the system, and the commitment to the technology demonstrated by management. To help distill these complex hidden factors, factor analysis has seen common use throughout the information systems field (e.g Tan and Lo, 1990; Moore and Benbasat, 1991; Pinto and Onsrud, 1993).

This research used factor analysis in an exploratory fashion to group together those GIS adoption response variables that were correlated across the 82 surveyed GIS users. Exploratory factor analysis is typically performed in the early stages of research, when it provides a tool for reducing the number of variables or examining patterns of correlations among variables without a serious intent to test theory. Under these circumstances, both the theoretical and the practical limitations to factor analysis can be relaxed in favor of a frank exploration of the data (Tabachnik and Fridell, 1989).

Final Influence Scales Retained for Modeling of GIS Use and Satisfaction

Appendix C provides the details of the factor analysis technique used to collapse the 52 original influences used in the survey into 12 groups of common factors found across the sample of GIS users at the surveyed installations. Table 6-1 defines those 12 factors and their composite items subsequently used to model the individual outcomes of GIS adoption as of the survey date.

Table 6-1. Common Factors Influencing Personal GIS Adoption at Surveyed Installations	
<u>Organizational Support</u> Top management support Continuity of skilled GIS manpower Management perception of GIS cost effectiveness Dedicated GIS manpower GIS implementation structure GIS integration into standard operations Organizational ability to purchase spatial data Attitude of GIS management Organizational position of GIS manager Supervisory appreciation for GIS benefits <u>Ease of Applying GIS</u> Functionality of the GIS software Utility of the spatial data model Satisfaction with technical support Availability of GIS technical documentation Ease of use of the GIS (i.e. point and click) <u>Benefits to User</u> Ability to perform new tasks Ability to reduce decision risk Ability to produce higher quality products Ability to increase job productivity <u>Confidence in Database Quality</u> Confidence in positional accuracy Confidence in attribute accuracy Confidence in data currency	<u>GIS Linkages</u> AM/FM/CADD-GIS Links Organizational digital database-GIS Links <u>Analog-to-Digital Conversion</u> Analog-to-Digital conversion work <u>GIS Use Access</u> Ease of physical access to the GIS Work hours available to use the GIS Requests for GIS chauffeuring <u>Relative Advantage to Using GIS</u> <u>Procurement of Capable Hardware</u> Utility of GIS hardware Importance of GIS champion <u>GIS Training</u> <u>GPS/Remote Sensing Knowledge</u> Ability to apply GPS knowledge Ability to apply remote sensing knowledge Familiarity with computer systems <u>Knowledge of Other GIS Adopters</u> Knowledge of GIS efforts at other sites Awareness of previous computer efforts

Models of Personal GIS Adoption Responses

A stepwise multivariate regression statistic was used to determine which of the influence factors identified through the iterative factor analyses were most significant in explaining the three specific adoption outcomes noted earlier in Figure 6-3. Extremely conservative modeling parameters were used to ensure very high confidence could be placed in the results.

Figure 6-4 conceptually portrays the results of the statistical modeling. The *GIS Use Access and GIS Training* factors identified in Table 6-1 were common predictors of all three of the adoption outcomes. The *GIS User Benefits* factor was a common predictor of both user satisfaction and direct GIS use. The *Confidence in Database Quality* and *Organizational GIS Support* factors also were found to significantly contribute to an individual's degree of satisfaction with their organizational GIS. Finally, the *GIS Linkages* factor was found to be a distinct contributor to an individual's combined GIS use

across the surveyed installations. The ramifications of these findings for GIS programs across the tri-services will be addressed further in Chapter 8.

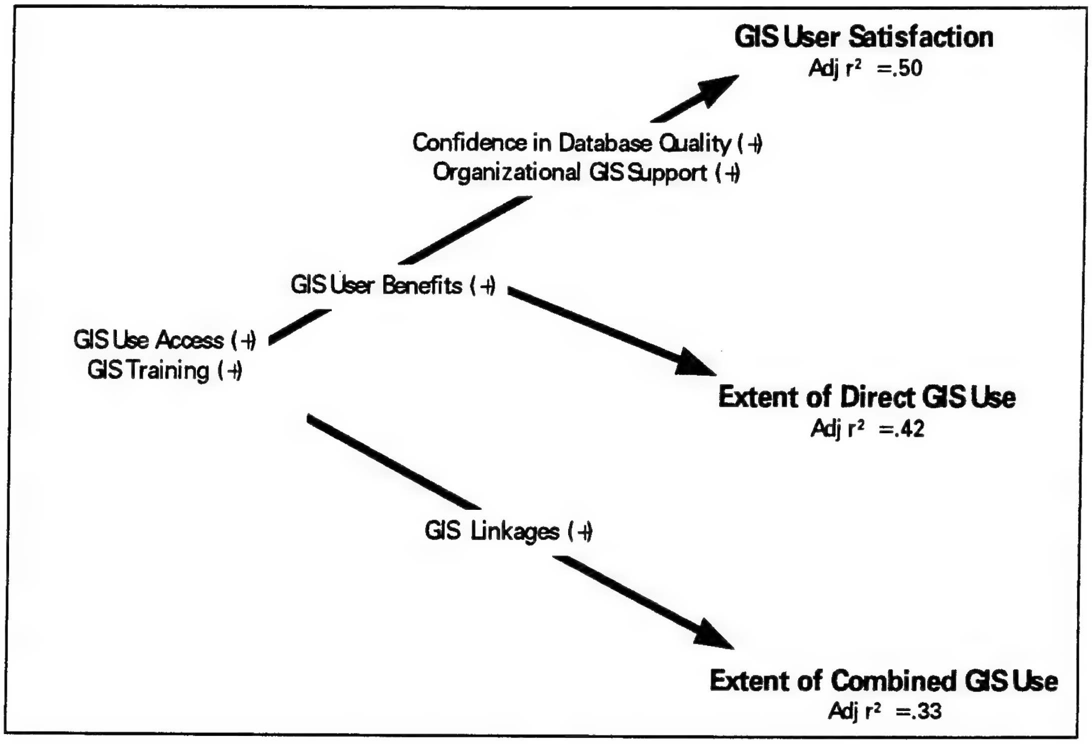

Figure 6-4. Model of Personal Adoption Responses and their Key Predictors

7 The Roles of Remote Sensing and GPS Technologies in Personal GIS Adoption

The effective use of GIS technology can rarely be accomplished today without the aid of remote sensing and global positioning system (GPS) technologies. In sum, these three spatial technologies have been considered the foundation elements to another GIS known as geographic information *science* (Abler, 1992). The ability of a GPS unit to provide accurate positional data in a cost effective manner has quickly established this technology as an essential component to an organizational GIS. Likewise, remote sensing technology is now viewed as a primary means of efficiently gathering large, synoptic views of the earth's surface which can then be digitally analyzed to reveal a wealth of new spatial data which can rapidly integrated into a GIS. Readers should be reminded that the results described in this chapter reflect the opinions of GIS users across a sample of mostly environmental organizations. The results may not mirror those who are seeking to employ GIS for more spatially detailed work such as infrastructure management.

GIS managers were asked several questions about the role of GPS and remote sensing in their GIS programs during their personal interviews. In addition, direct system users were asked to identify the extent to which their ability to apply their personal knowledge of GPS and remote sensing influenced their GIS use in Part II of the GIS User Survey. Finally, all GIS users were asked in Part V of the GIS User Survey to respond to a series of more detailed questions about remote sensing and GPS.

Remote Sensing Technology

Remote Sensing Data Sources Employed. GIS managers were asked to provide an inventory of their imagery. Table 7-1 shows analog aerial photos were the most common source of imagery, followed closely by digital LANDSAT Thematic Mapping (TM) and then SPOT multi-spectral (XS) imagery. The majority of the installations using the latter two stated that they had acquired the imagery through the USACE Civil Engineering Research Laboratories.

Table 7-1. Remotely Sensed Imagery In Use at Tri-Service Installations

Data Source	No. of Installations	Percent of Total Installations
LANDSAT MSS	0	0%
LANDSAT TM	18	50%
SPOT XS	12	33%
SPOT PAN	5	13%
AERIAL PHOTOS	19	53%
AIRBORNE MSS	3	8%
AVHRR	1	2%
DIGITAL ORTHOPHOTOS	1	2%

Extent of Remote Sensing Expertise. GIS users were asked to describe any remote sensing training they had received. These individuals were then asked to quantitatively describe the degree to which they felt their training had made them capable of applying remote sensing expertise to their GIS applications. A seven-point scale ranging from 'Not Capable' to 'Extremely Capable' was used and the responses collapsed into the five frequency columns noted in Figure 7-1. The skewed distribution highlights the disproportionate number of GIS users who felt incapable of applying any remote sensing knowledge. Since Table 7-1 noted a wide use of imagery being exploited, a valid issue of concern is the validity of GIS analyses including remotely sensed data.

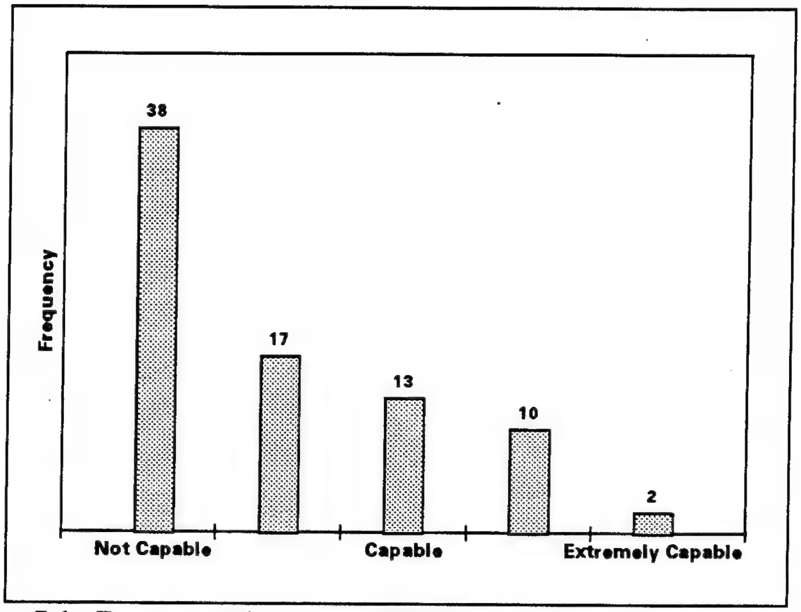

Figure 7-1. Frequency Histogram of GIS User's Remote Sensing Capability

Average Importance of Remote Sensing Issues to GIS Use. GIS users were asked to respond to a series of five questions to clarify just how much remote sensing knowledge they felt was necessary for them to make effective and responsible use of their GIS. Figure 7-2 shows their average responses using a five-item scale.

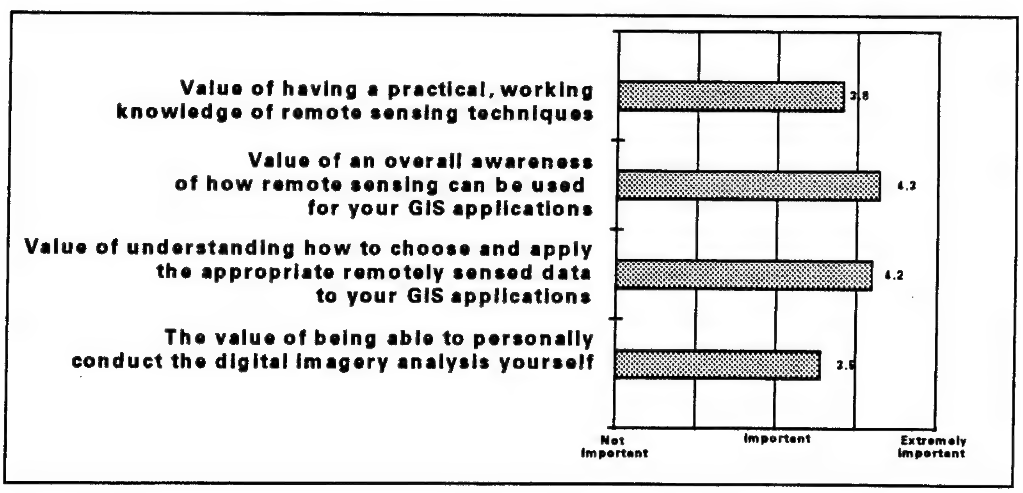

Figure 7-2. Relative Importance of Remote Sensing Issues to Tri-Service GIS Users

GIS users felt their most important need was to gain an overall awareness of how remote sensing could be used in their applications. This was closely followed by having an understanding of how to not only *choose* the appropriate data for their applications, but then knowing how to *apply* the information. GIS users rated as third in importance having a practical, working knowledge of general remote sensing techniques. An ability to personally conduct the digital imagery analysis themselves was rated lowest, but still was considered important (3.5).

Global Positioning System (GPS) Technology

The Importance of Spatial Accuracy. GIS users were asked to describe the level of accuracy they required in the majority of their GIS applications. The multiple choice question offered five different answers, each which reflected a different configuration of GPS equipment ranging from a single GPS unit recording data in a Civilian Acquisition mode to sub-meter accuracies obtainable through post-processing and total stations. Figure 7-3 shows the majority of GIS users classified their needed accuracies as less than plus or minus 15 feet. The survey found that hazardous waste applications and endangered species management routinely demanded extremely accurate spatial data for tagging bore holes or red-cockaded woodpecker (RCW) cavity trees. Those users accepting poorer accuracies were typically dealing with 'fuzzy' boundaries of natural phenomena such as delineating ecotones.

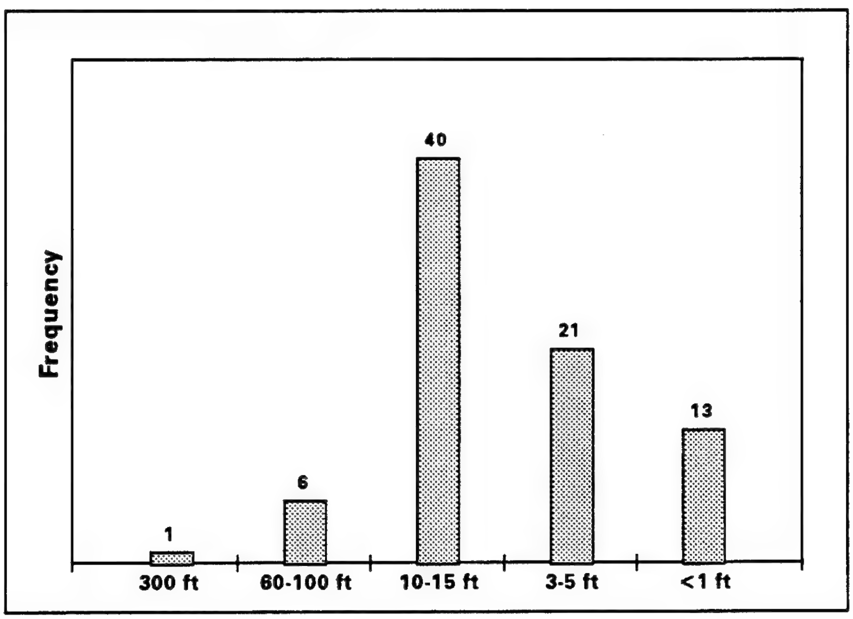

Figure 7-3. Frequency Histogram of Positional Accuracies Required by GIS Users

Organizations with GPS Technology. GIS managers were asked whether their organization had invested in GPS technology. Figure 7-4 shows GPS technology is now being used at a majority of installations. Earlier in Chapter 3 it was shown the median level of GPS investment at these sites was about $12,000.

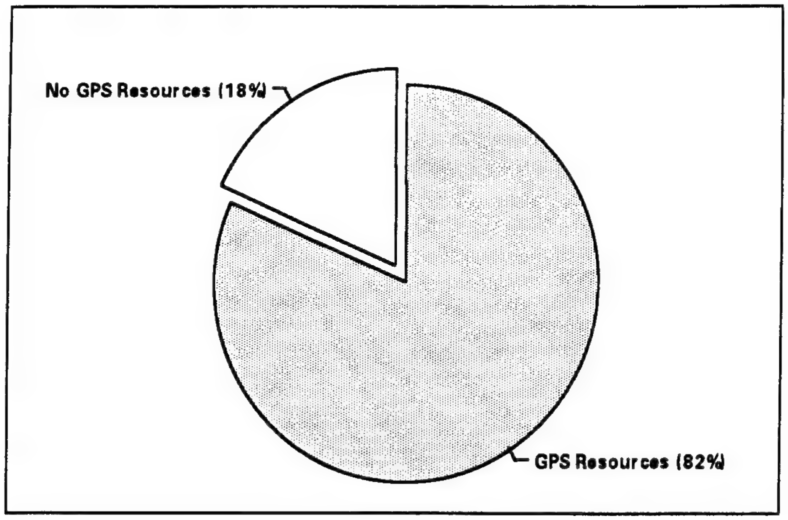

Figure 7-4. Availability of GPS Resources at Surveyed Installations

Extent of GPS Experience. GIS users were asked to describe any GPS training they had received and then to quantitatively describe the degree to which they felt their training had made them capable of applying this knowledge to their GIS applications. A seven-point scale ranging from 'Not Capable' to 'Extremely Capable' was used and the responses collapsed into the five frequency columns noted in Figure 7-5. Compared to the distribution of remote sensing capabilities found earlier in the chapter, the GPS capability distribution was much more evenly distributed, though the numbers suggest a situation of 'haves' and 'have-nots'. As the rapid diffusion of GPS continues and more GIS users become aware of the ease with which they can learn to efficiently acquire very precise data in a relatively short period of time, this distribution will likely undergo a dramatic shift to the right.

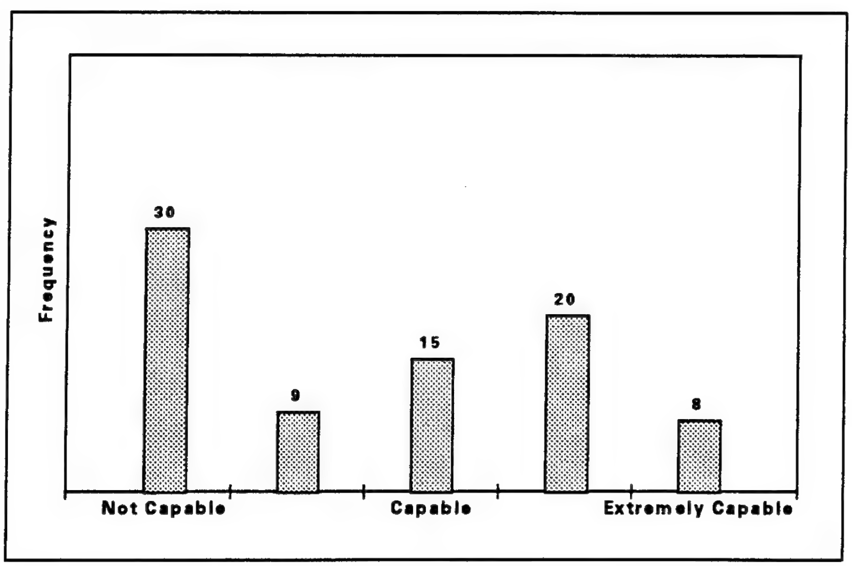

Figure 7-5. Frequency Histogram of GIS User's GPS Capability

Importance of GPS to GIS Use. GIS users were asked to clarify just how much knowledge of GPS technology they needed to make effective and responsible use of their GIS. A five-item scale ranging from 'Not Important' to 'Extremely Important' was used to capture their responses. Figure 7-6 lists the items asked and the average responses. GIS users felt that both an awareness and an ability to personally acquire and then integrate the GPS data were extremely important to their effective and responsible use of the GIS. Again, similar to the trends towards remote sensing, the GIS users felt similarly towards the need for increased awareness of GPS technology.

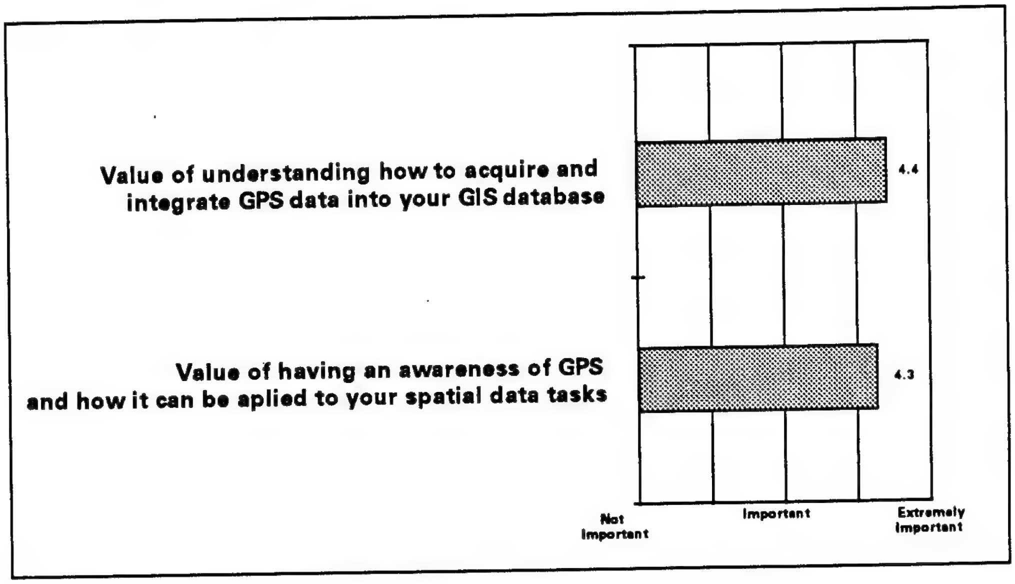

Figure 7-6. Relative Importance of Remote Sensing Issues to Tri-Service GIS Users

The Impact of Spatial Technology Awareness on GIS Use. After reviewing the information in this chapter, can it be concluded that enhancing the surveyed GIS user's awareness of remote sensing and GPS technologies would effectively increase an organization's use of their GIS? According to the GIS use model calculated in the previous chapter, the answer to this question is 'No.' However, more careful scrutiny will show otherwise.

The 'GPS/Remote Sensing Knowledge' factor never appeared as a significant predictor of GIS use (see Figure 6-4). However, the predictive models were calculated across the entire sample of GIS users, including both those who were very knowledgeable in these related spatial technologies and those who were not. Therefore, two sub-groups were created from the GIS users to perform some comparative tests.

Original Hypothesis: The extent to which an individual makes direct use of their GIS was not enhanced by a person's ability to apply their combined GPS and remote sensing knowledge

Alternative Hypothesis: People who had an ability to apply their knowledge of GPS and remote sensing technologies would make more use of their GIS than those lacking this knowledge.

Test: All those GIS users who described themselves as at least 'Capable' (4 or higher) on *both* of the capability scales used in Part V of the GIS User Survey were placed in the 'Capable' sub-group (N=19). All those who scored *less* than 4 on *both* scales were placed into the 'Not Capable' sub-group (N=33). A stepwise linear regression was performed on each of these groups using the same scales described in the previous chapter and the analytical results are found in Appendix C. The dependent variable for both regressions was the 'Extent of Direct GIS Use'. Figure 7-7 shows the results of the analyses.

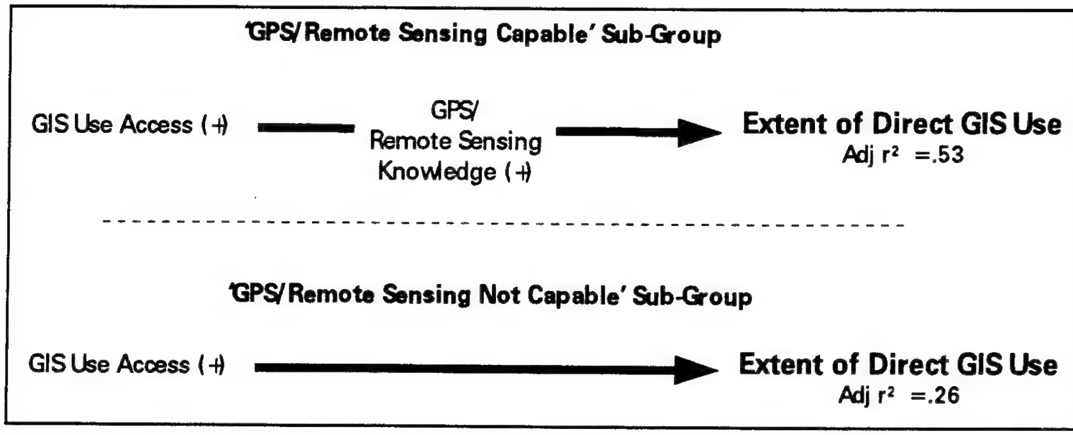

Figure 7-7. Modeling the Influence of GPS/Remote Sensing Knowledge on Direct GIS Use

Discussion of Results: The 'GPS/Remote Sensing Knowledge' influence scale was a significant facilitator to the 'Extent of GIS Use' outcome for the subgroup of GIS users who described themselves as capable of applying remote sensing and GPS knowledge to their GIS applications. The same construct was not found to be statistically significant for the second subgroup of GIS users who were incapable of applying remote sensing and GPS knowledge to their GIS applications.

The information presented in this chapter comprises the first large scale investigation of the roles played by the complementary technologies of remote sensing and GPS to GIS adoption success. Indeed these three spatial information technologies share a mutually facilitating role and should be recognized as important contributors to the successful implementation of GIS on military installations.

8 Summary of Findings and Recommendations

Before any summaries of the findings are presented, the research limitations need to be reiterated to avoid any misinterpretations. First of all, these findings portray the status of a limited number of GIS implementations at a single point in time. Secondly, the research strategy purposefully constrained the number of variables and organizational echelons included for practical and logistical reasons. Finally, there were at least fifty-five organizations in the early stages of GIS development who were not included in the survey since they did not meet the objective criteria necessary for this specific research. In addition, the US Army Corps of Engineers, one of the lead agencies in the application of CADD/GIS technologies, as well as the military's research and development laboratories, were not included since they did not meet the specific sample requirements. The exclusion of all these agencies should in no way reflect negatively on the many years these organizations have been pursuing GIS aims. To the contrary, many laboratories and Corps districts have served as technical GIS points of contact for the military installations. However, the necessarily limited purpose and scope of this research allowed much greater confidence to be placed on the results obtained.

General Research Findings

The organizational profiles presented in Chapter 3 certainly point to the relative immaturity of most programs; not in terms of actual time, but in terms of benefits derived to date versus their potential. A mature implementation would probably possess strategic and tactical plans for the full exploitation of their acquired GIS resources, a fully populated database with standard procedures in place to maintain the integrity of the data, a wide number of direct, indirect and combined users across the organization serving multiple mission support needs requiring spatial data, and an organizational culture which values GIS technology as essential for more effective mission support.

The reality of situation is that few field-level organizations have either the human or fiscal resources to implement GIS technology 'by the book'. In a period of real downsizing and budget reductions, *any* organization would find it extremely difficult to manage technological change amidst so much organizational change. These *real obstacles* found during the field visits only serves to point out how critical it is for organizations to become aware of the many obstacles inherent to trying to achieve *real benefits* from their GIS. As the senior managers and the GIS managers expressed in looking back at their GIS experiences, a lack of awareness prior to their adoption should serve as a key "lesson learned" to be shared with others (refer to Figure 2-1). A lack of awareness for the value of planning, establishing objectives, and developing evaluation programs was more than evident across the surveyed sites. The successful adoption of GIS has to be perceived as much more than just successfully acquiring the hardware and software. To the contrary, equipment purchases is one of the *last* steps to be accomplished if an organization were following widely-endorsed GIS implementation models (Marble, 1992).

What constitutes a successful outcome to a GIS implementation? The research models used individuals as the unit of analysis, measuring their personal use and user satisfaction. This unit of analysis, however, and the outcomes selected were only a first step in accomplishing a very important process for all installations: carefully accounting for the significant GIS investments made to date by providing direct evidence of the impact of GIS on mission effectiveness. As the techno-euphoria begins to wane and the implementation costs mount over the years, it will become increasingly important to emphasize the outcomes to GIS adoption. As the organizational managers reported, it was extremely important for continued funding of their GIS programs that such emphasis be given to providing them with a means of specifically identifying the tangible contributions of GIS.

Assuming maximum personal use and satisfaction with the GIS is a desired outcome, what factors have proven to be the greatest contributors to these ends? Figure 6-4 clearly showed that providing individuals with access to the GIS as well as providing them with adequate training were common factors contributing to positive adoption outcomes. The models also showed that if an individual is made aware of the many benefits they could derive through GIS use, both their amount of use and their perceived satisfaction would certainly increase. End users were also aware that all databases are not made equal since user confidence in the database quality was a significant contributor to GIS satisfaction. Poor data makes for ill-informed decision-making which can yield tragic consequences. Finally, the perceived level of organizational support for the GIS was also found to be a significant contributor to GIS user satisfaction. Whether it is the amount of support for GIS expressed by top management, the attitude of a GIS user's superior towards the technology, or the organization's willingness to commit a manpower authorization to manage the GIS program, all of these influences together comprise the perceived level of organizational support. The sustainment of GIS technology over the long-term cannot survive without the *active* support of the larger organization.

An interesting contributor to the extent of combined GIS use across the surveyed organizations was the ability of the organizational GIS to link with other established databases in the unit. Whether it be a CADD data set used for utility management or an ASCII data set provided by the local US Fish and Wildlife office, the GIS will see more total use if these external data sets are being exploited.

The immense costs of database development can be mitigated through the cost-effective acquisition of remotely sensed data sets and the use of GPS technology. Chapter 7 demonstrated that across those organizations surveyed, individuals who had been provided with an ability to exploit their knowledge of remote sensing and GPS found these tools to be significant catalysts to increased use of the GIS. The accuracy and costs of populating databases, the responsible employment of remotely sensed data for decision-making, and the increased use of the GIS are general benefits to be gained by providing field-level personnel with expanded awareness of the remote sensing and GPS components to geographic information processing.

Assessing Your Organization's Current GIS Adoption Behavior

This research has provided new insights into the common trends found across a sample of tri-service organizations. However, the value of the findings notwithstanding, of what specific value is the research to the GIS manager at installation 'X'? Their successful

adoption will be defined by those individuals and their accompanying social "gates" found at their local site. Though the research aim was to ascertain broad, common implementation trends, the findings also provide installations with a practical (albeit initial) and valuable means of understanding their own local implementation.

The first step in appreciating the current status of an installation's adoption situation is to build a global view of the local users. Using these two adoption responses of GIS direct use and user satisfaction, Figure 8-1 shows how individual GIS adoption responses can be mapped. The two scaled dimensions of satisfaction and use can be further subdivided into four quadrants: high use and high satisfaction ("successful'), low use and low satisfaction ("unsuccessful"), high use and low satisfaction ("unconvinced"), and low use and high satisfaction ("potential"). Using this mapping scheme, outliers beyond the "successful" cluster can be identified and examined for means to move the actors towards the "successful" domain.

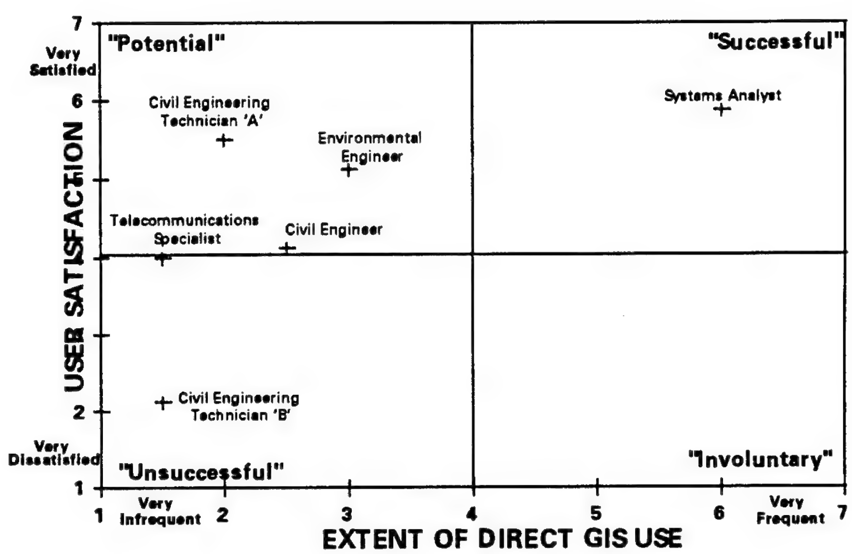

Figure 8-1. Current Personal GIS Implementation Outcomes for Installation 'X' Users

'Installation X' would appear to have a relatively immature, yet healthy GIS implementation underway; only one individual reported low use and satisfaction, while all others showed potential or existing adoption success. What accounts for this variation in individual GIS use and satisfaction? The 12 scales developed during the course of the research can provide this information now to the GIS Program Manager. Three of these GIS users will be examined more closely to show how this research can aid understanding GIS use behavior.

The Systems Analyst at Installation 'X' recorded high satisfaction and very frequent direct use. This would be termed "successful" behavior using the two surrogates

employed in this research and a goal for all intended users. Though this statement reflects a pro-innovation bias, it is stated with the assumption that the technology has been evaluated and met all technical performance criteria and has the capacity to meet both user and organizational needs. A profile of the scale averages for the System Analyst, who happened to be a full-time GIS staff member, can be graphically portrayed (Figure 8-2). None of the influences were identified as inhibiting his adoption responses.

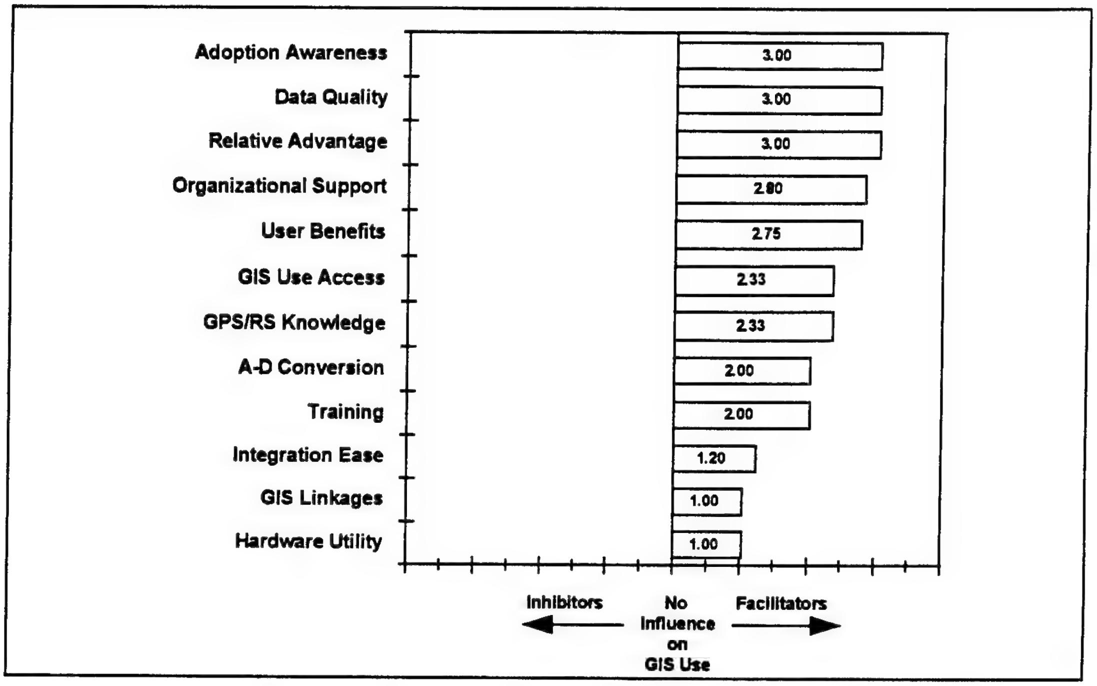

Figure 8-2. GIS Adoption Response Profile for 'Systems Analyst'

The Civil Engineer, however, was mapped on the border of the "Potential" and "Unsuccessful" domains. This individual reported three influence scales as inhibiting his GIS use: *GIS Use Access, Hardware Utility*, and *Organizational Support* (Figure 8-3). This individual was a key advocate for the GIS program within the civil engineering function, and was well trained in both GIS, GPS and remote sensing technologies. However, he perceived the organization was not supporting the GIS implementation. The three inhibitors point to this fact since they are all a result of organizational resistance to modifying their fiscal or operating priorities.

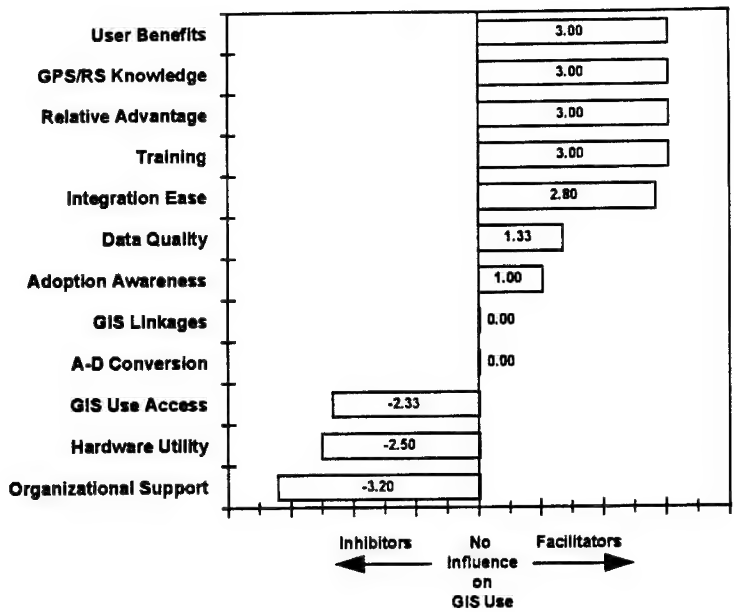

Figure 8-3. GIS Adoption Response Profile for 'Civil Engineer'

The individual warranting the most concern was Civil Engineering Technician 'B' who reported very low direct use and satisfaction. This individual had graduated from technical school less than a year prior and had about seven months of limited GIS use when the survey was administered. This individual was also only temporarily filling his current GIS duties since he was soon to be transferred. The resulting adoption response profile accurately portrays this apathy through the lack of extreme scores compared to the previous two profiles (Figure 8-4).

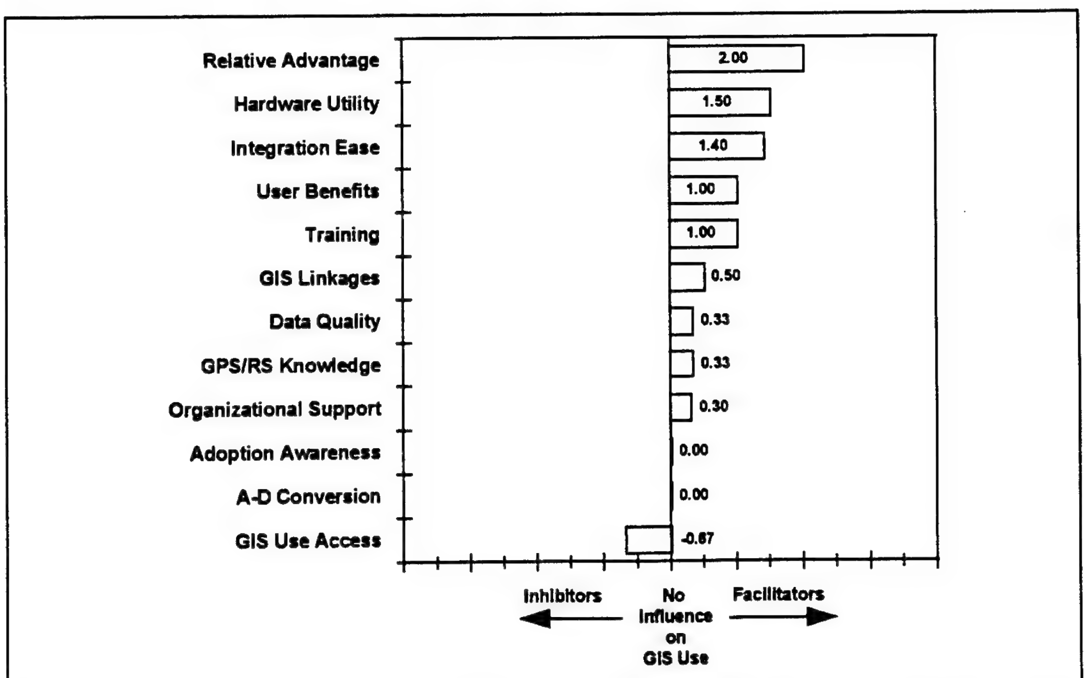

Figure 8-4. GIS Adoption Response Profile for 'Technician B'

The GIS Program Manager is tasked with 1) improving the effectiveness of the GIS and the organization; 2) anticipating GIS user reactions, attitudes and behavior; and 3) reinforcing supportive GIS user behavior or mitigating the effects of disruptive behavior (Maish, 1979). These three examples demonstrate how the set of developed scales can effectively assist the GIS Manager in accomplishing these difficult tasks. While this initial administration was conducted by an outside third party, future administrations using the refined scales would not require the application of multivariate statistics since only averages would need to be calculated.

The three profiles and the GIS implementation behavior map of Installation 'X' demonstrate how the research findings can be used in a practical manner to assist with GIS implementations on any given tri-service installation. While this initial administration was conducted by an outside third party, future administrations using the refined scales would not necessarily require the application of multivariate statistics since only averages would need to be calculated. There is substantial merit, however, in having comprehensive program assessment periodically performed by an objective third party who would not be seen as carrying any local biases.

This methodology for assessing GIS implementation progress through individual adoption success surrogates is an initial, exploratory venture with much work still to be done. The value of this initial strategy, however, lies not only in its simplicity but moreso in the fact there are no other means readily available for tri-service GIS managers to conduct a structured evaluation of their adoption responses.

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APPENDIX A. Installation GIS Programs Surveyed

Table A-1. List of Installation GIS Programs Surveyed

Site	State	Service	GIS User Domains Surveyed	Date of Site Visit
Aberdeen Proving Grounds	MD	USA	Environmental	May 94
Avon Park AFR	FL	USAF	Environmental	Feb 94
Camp Lejeune MCB	NC	USMC	Installation	May 94
Crane NSWC	IN	USN	Natural Resources	Apr 94
Dare County AFR	NC	USAF	Environmental	May 94
Edwards AFB	CA	USAF	Installlation	Feb 94
Eglin AFB	FL	USAF	Environmental	Dec 93
Fort Benning	GA	USA	Environmental	Apr 94
Fort Bliss	TX	USA	Environmental	Dec 93
Fort Bragg	NC	USA	Environmental	Oct 94
Fort Carson	CO	USA	Environmental	Mar 94
Fort Chaffee	AR	USA	Environmental	Jan 94
Fort Drum	NY	USA	Environmental	May 94
Fort Gordon	GA	USA	Environmental	May 94
Fort Hood	TX	USA	Environmental	Dec 93
Fort Knox	KY	USA	Environmental/Public Works/Firing Range	Apr 94
Fort Leonard Wood	MO	USA	Environmental	May 94
Fort Lewis	WA	USA	Environmental	May 94
Fort McCoy	WI	USA	Environmental	May 94
Fort Polk	LA	USA	Environmental	Jan 94
Fort Riley	KS	USA	Environmental	May 94
Fort Sill	OK	USA	Environmental	Jan 94
Hill AFB	UT	USAF	Environmental	May 94
Idaho ARNG	ID	USARNG	Environmental	May 94
Indiana ARNG	IN	USARNG	Natural Resources	Apr 94
Michigan ARNG	MI	USARNG	Environmental/Firing Range	May 94
Minnesota ARNG	MN	USARNG	Environmental	May 94
Mississippi ARNG	MS	USARNG	Environmental	Jan 94
Nellis AFB	NV	USAF	Firing Range	Feb 94
Patrick AFB	FL	USAF	Base Development	Apr 94
Patuxent River NAS	MD	USN	Installation	Mar 94
Peterson AFB	CO	USAF	Base Development	Mar 94
Pine Bluff Arsenal	AR	USA	Environmental	Jan 94
Quantico MCB	VA	USMC	Environmental	Mar 94
Texas ARNG	TX	USARNG	Environmental	Dec 93
USAF Academy	CO	USAF	Natural Resources	Mar 94
White Sands Missile Range	NM	USA	Environmental	Dec 93
Yuma MCAS	AZ	USMC	Environmental	Oct 94

APPENDIX B SURVEY INSTRUMENTS

GIS USER SURVEY

SENIOR MANAGER SURVEY

GIS MANAGER SURVEY

PERSONAL INTERVIEW QUESTIONS FOR SENIOR MANAGERS AND GIS MANAGERS

A SURVEY OF GIS ADOPTION RESPONSES
on
DEPARTMENT OF DEFENSE INSTALLATIONS

GIS USER SURVEY

PRIVACY ACT STATEMENT:

AUTHORITY: 5 USC 301, 10 USC 8012

PURPOSE: To assess the factors contributing to the successful implementation of GIS technology by field-level organizations on Department of Defense installations.

ROUTINE USES: Information gathered through this survey will be used in support of Department of Defense objectives seeking to maximize the productivity of the federal GIS technology investment across military installations.

STATUS OF RESPONDENT PARTICIPATION: Participation is voluntary.

ACTIONS TO BE TAKEN IF ALL OR PART OF THE REQUESTED INFORMATION IS NOT PROVIDED: No action will be taken if the members do not wish to complete this questionnaire.

INSTRUCTIONS:

You have been identified as an individual who:

1) has received training in the use of your organization's GIS; and
2) has enough experience with the GIS to capably identify issues affecting your extent of use and satisfaction.

This survey will help assess what influences have either encouraged or hindered your use of the GIS.

Part I will first ask you for some personal background information.
Part II will ask you how several issues have influenced your current GIS use.
Part III includes questions to measure your overall GIS use and satisfaction.
Part IV asks you to describe how you specifically apply the GIS to your duties.
Part V includes questions on your use of remote sensing and GPS technologies.

It would be very helpful if you could provide your name and organization so your personal involvement with the GIS could be evaluated in another two years. Under no circumstances will your specific responses to this survey be attributed to you personally without your expressed permission.

Please feel free to include any comments you may have on the last page of this survey.

Name: ____________________________ Organization: ____________________________

PART I. BACKGROUND INFORMATION

1. Please circle your current duty responsibilities. (Circle two items if they apply)

GIS Program Manager	Management (e.g. Chief, Env Flight)
GIS Staff Member	Support (e.g. Forester)

2. Please provide your job title (Civil Service-GS-series/Pos Title; Contractor; Military-Rank)

____

3. Please circle your gender and indicate your age M / F Age______

4. Please circle your currently achieved level of academic education

1	2	3	4	5	6	7
H.S. Diploma	Earned College Credits	Bachelor's Degree	Post-Bachelor's Credits	Master's Degree	Post-Master's Credits	Doctoral Degree

5. How long have you been working for the US Government? ______ Years ______ Months

6. How much GIS experience did you have in other jobs? ______ Years ______ Months

7. How long have you been trained to use your current GIS? ______ Years ______ Months

8. What percent of your current GIS use is devoted to generating products for *others*?

1	2	3	4	5	6	7
0%	Between 0 and 25%	Between 25 and 50%	50%	Between 50 and 75%	Between 75% and 100%	100%

9. Please indicate the GIS software package you *most frequently use*.

ARC/INFO GRASS MGE Other ______________________

10. How much CADD experience have you had? ______ Years ______ Months

What CADD package(s) have you used (if any)? ______________________

11. How would you describe your overall use of computers *prior* to using the GIS? (Circle One)

1	2	3	4	5	6	7
No Computer Use Prior to GIS			Some Computer Use Prior to GIS			Extensive Computer Use Prior to GIS

12. Were you asked *your specific spatial data needs* to help create the GIS database? Yes / No

13. Please describe any GIS training you have received to include the ***source*** (provided by vendor or by in-house staff), ***type*** (e.g. formal at vendor site or informal on-the-job), and ***length*** (e.g. 3 day course).

____

____

PART II. INFLUENCES ON GIS USE

Please show how the following factors have either ***positively*** or ***negatively influenced your effective use of the GIS*** and then circle the appropriate number.

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative ... Extremely Positive

1. The extent to which your service headquarters (USAF, USA, USN/USMC, ARNG) actively supports your GIS program

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative ... Extremely Positive

2. The extent to which your supervisor understands the benefits of using GIS technology

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative ... Extremely Positive

3. The ability of your GIS Program Manager to provide direction to all offices, given their *position in the organization*

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative ... Extremely Positive

4. The degree that unit senior management is convinced GIS benefits outweigh all the costs

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative ... Extremely Positive

5. The *attitude* of GIS program management in helping you overcome problems in using the GIS

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative ... Extremely Positive

6. The degree that the GIS has been integrated into the organization's standard operating procedures

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative ... Extremely Positive

7. The degree of real, active GIS support provided by your organization's top management

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative ... Extremely Positive

8. Your personal knowledge of how GIS efforts at other installations like yours have performed.

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative ... Extremely Positive

9. The extent of your GIS training in allowing you to perform your desired tasks

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative ... Extremely Positive

10. The extent to which your job series or position descriptions reflect your GIS activities.

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative ... Extremely Positive

REMEMBER:

HOW DO THESE ISSUES INFLUENCE YOUR USE OF THE GIS SYSTEM?

11. The time you have to use the GIS while still meeting your *current* job requirements	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
12. Your understanding of technical computer issues such as baud rates or how to install new equipment	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
13. Perceived resistance to supporting GIS use from members within your service who currently use CADD systems	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
14. The importance of a "GIS Champion" to your *current* use of the GIS	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
15. The feeling that your feedback to GIS developers about problems is being addressed	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
16. Your ability to learn and apply the changes included in the software upgrades you receive	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
17. The advantages of using the GIS for your tasks compared to other methods you would use	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
18. Your ability to apply knowledge of remote sensing techniques to your GIS applications	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
19. Your ability to apply Global Positioning System (GPS) technology to your GIS applications	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
20. Requests from those not trained to operate the GIS to have you generate GIS products	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive

21. The extent to which your initial expectations of the system have come true

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative — Extremely Positive

22. The number of people *dedicated* to GIS management support in the organization

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative — Extremely Positive

23. The presence of mission requirements that can *only* be satisfied with the GIS

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative — Extremely Positive

24. The degree to which you are *personally* motivated to change the way you do your job by using the GIS

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative — Extremely Positive

25. The perceived increase in job prestige by using the GIS to help in your duties

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative — Extremely Positive

26. The perceived increase in job productivity from using the GIS

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative — Extremely Positive

27. The ability to produce *higher quality products* (e.g. maps, tables)

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative — Extremely Positive

28. The ability to *reduce* the amount of *risk* or *uncertainty* in your tasks by using the GIS

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative — Extremely Positive

29. The ability to perform new tasks not previously possible

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative — Extremely Positive

30. Your knowledge about *previous* computer system efforts in your organization

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative — Extremely Positive

31. The ease of using just the *database management system* attached to your GIS

-4 -3 -2 -1 0 +1 +2 +3 +4

Extremely Negative — Extremely Positive

REMEMBER:

HOW DO THESE ISSUES INFLUENCE YOUR USE OF THE GIS SYSTEM?

	-4	-3	-2	-1	0	+1	+2	+3	+4
32. Your satisfaction with the quality of outside commercial or military technical support (whichever is applicable to your system)	Extremely Negative								Extremely Positive
33. Availability of technical GIS documentation to help you use the system	Extremely Negative								Extremely Positive
34. The usefulness of the data model selected for *your* specific applications (e.g. Does your vector or raster system limit your applications?)	Extremely Negative								Extremely Positive
35. The ability to physically link the GIS with *digital* databases existing in the organization	Extremely Negative								Extremely Positive
36. The ability to link the GIS with AM/FM/CADD systems *currently found* in the organization	Extremely Negative								Extremely Positive
37. The ease of getting *to* the GIS to use it (i.e. Is it in another building or on your desk?)	Extremely Negative								Extremely Positive
38. The ability of the GIS *hardware* (e.g. size of memory, monitor resolution, etc) to support your desired applications	Extremely Negative								Extremely Positive
39. The reliability of the GIS (i.e. How does the frequency of system downtime influence your use?)	Extremely Negative								Extremely Positive
40. Technical ability of the GIS *software* to support your desired applications (i.e. Does the software do everything you need?)	Extremely Negative								Extremely Positive
41. The ease of actually using the GIS to obtain information (i.e. 'point and click' or series of typed commands?)	Extremely Negative								Extremely Positive

42. Your current ability to readily exchange data and system information with other GIS sites	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
43. Your confidence in the *currency* of the GIS data you use	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
44. Your confidence in the *positional accuracy* of the GIS data you use	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
45. Your confidence in the *attribute accuracy* of the GIS data you use	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
46. The effort you have to spend to change existing information such as paper maps, files or airphotos into a digital form	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
47. The effort you need to expend to change available automated data (e.g. existing computer databases) into a format understood by your GIS	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
48. The *current availability* of *digital* data sets for your applications (e.g. Is it readily available from the USGS or USFWS?)	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
49. The ability of the organization to pay for the *cost* of acquiring the necessary data for your particular application	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
50. The degree to which you feel the organization is implementing the GIS in a structured, informed manner	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
51. The ability of the organization to *acquire* and *retain* individuals with GIS skills	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive
52. The degree to which you feel the use of standards (hardware, software, data transfers) may influence your GIS use	-4 Extremely Negative	-3	-2	-1	0	+1	+2	+3	+4 Extremely Positive

PART III. GIS USE and SATISFACTION

Question	1	2	3	4	5	6	7
1. The degree to which you are dependent on the GIS to perform your mission tasks.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
2. The degree to which your use of the GIS increases your job satisfaction.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
3. The degree to which the GIS is convenient for you to use.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
4. The degree to which the GIS enables you to carry out your mission tasks easily and efficiently.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
5. The degree to which the information provided to you by the GIS is accurate and reliable.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
6. The degree to which the GIS is contributing to achieving organizational mission goals and objectives.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
7. The degree to which the GIS can be easily adjusted to new conditions, demands and circumstances of the organization.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
8. The degree to which the information provided to you by the GIS is sufficient for you to perform your mission tasks.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
9. Please circle how often you make ***direct, hands-on use*** of the GIS to assist with *your* duties.	1 Infrequently	2	3	4	5	6	7 Frequently

10. Please check the box which best describes how often you currently make ***direct, hands-on use*** of the GIS to assist *you* in *your* duties.

- ☐ Not at all
- ☐ Less than once a week
- ☐ About once a week
- ☐ 2-3 times a week
- ☐ 4-6 times a week
- ☐ About once a day
- ☐ More than once a day

11. Please circle how often you make ***indirect, "hands-off" use*** of the GIS by having others generate products that *you* use to perform *your* duties.

1	2	3	4	5	6	7
Infrequently						Frequently

12. Please check the box which best describes how often you currently make ***indirect, "hands-off" use*** of the GIS to perform *your* duties.

- ☐ Not at all
- ☐ Less than once a week
- ☐ About once a week
- ☐ 2-3 times a week
- ☐ 4-6 times a week
- ☐ About once a day
- ☐ More than once a day

PART IV. YOUR GIS APPLICATIONS

1. The GIS user usually moves from simple **inventory** queries (e.g. how many acres of wetland are on post?) to **analysis** (e.g. where are sites meeting these three criteria?) and then to **modeling** (e.g. what would happen if we built a dam at this point?). Please show how *you* personally are using the GIS to help with *your* tasks by listing your applications and whether the application involves inventory (I), analysis (A) or modeling (M). Since an application (e.g. forestry) may include all three, check all appropriate boxes.

(CHECK ALL THAT ARE APPROPRIATE)

BRIEF APPLICATION TITLE	INVENTORY	ANALYSIS	MODELING
______________________	☐	☐	☐
______________________	☐	☐	☐
______________________	☐	☐	☐
______________________	☐	☐	☐
______________________	☐	☐	☐
______________________	☐	☐	☐
______________________	☐	☐	☐
______________________	☐	☐	☐

PART V. REMOTE SENSING/GPS ISSUES

1. Please describe any remote sensing training you have received to include the ***source*** (provided by vendor), ***type*** (e.g. formal on-site), ***length*** (e.g. 3 day course), and ***image processing software*** (e.g. ERDAS). Mark 'None' if appropriate. Then circle the appropriate level of training on the scale.

____

____

Please circle the degree to which you feel the above training has made you capable of applying remote sensing expertise to your GIS applications.

1	2	3	4	5	6	7
Not Capable			Capable			Extremely Capable

Please rate how important you feel the four following remote sensing issues are to an individual's ability to responsibly apply GIS technology to environmental management.

2. A practical, working knowledge of remote sensing techniques

1	2	3	4	5
Not Important				Extremely Important

3. An overall *awareness* of what remote sensing is and how it can be used in your applications

1	2	3	4	5
Not Important				Extremely Important

4. An understanding of *how to choose and apply* the appropriate type of remotely sensed data to complement your GIS applications

1	2	3	4	5
Not Important				Extremely Important

5. The need to have the hardware, software and training available *on-site* for you to *personally conduct digital imagery analysis* (e.g. analog imagery scanning, image spectral analysis, image rectification, etc.) instead of having an outside agency perform this function.

1	2	3	4	5
Not Important				Extremely Important

6. How important is it to the majority of *your* GIS applications that the spatial locations of points, lines or areas be accurate?

1 2 3 4 5

Not Important ... Extremely Important

7. Please describe any GPS training you have received to include the ***source*** (e.g. vendor), ***type*** (e.g. formal on-site), ***length*** (e.g. 3 hr workshop), and ***hardware*** (e.g. TRIMBLE). Mark 'None' otherwise.

____

____

Please circle the degree to which you feel the above training has made you capable of applying GPS expertise to your GIS applications.

1 2 3 4 5 6 7

Not Capable ... Capable ... Extremely Capable

Please rate how important you feel the following two GPS issues are to an individual's ability to responsibly apply GIS technology to environmental management.

8. An *awareness* of what GPS is and how it can be used in environmental management.

1 2 3 4 5

Not Important ... Extremely Important

9. An understanding of how to *acquire* and *integrate* GPS data so more accurate GIS data layers can be developed and maintained.

1 2 3 4 5

Not Important ... Extremely Important

10. GPS equipment configurations have varying abilities to precisely record feature locations. Be aware that with increased feature positional accuracy comes increased cost. Please circle the precision level you require in the majority of your personal GIS applications.

➀ 300 ft ➀ 60 to 100 ft ➀10 to 15 ft ➀ 3 to 5 ft ➀ Less than 1 ft

11. Several installations have joint agreements with other government agencies (e.g. contracting with the US Fish and Wildlife Service to conduct wildlife surveys, sharing the costs of buying remote sensing data, using a GPS base station located at another government site). Please describe *any* current or planned joint ventures you are aware of related to *your* use of GIS/Remote Sensing/GPS technologies.

____

____

____

<u>**COMMENTS SECTION**</u>

SENIOR MGR VIEW OF GIS PERFORMANCE

	1	2	3	4	5	6	7
1. The degree to which you are currently satisfied with the return on your organization's GIS investment.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
2. The degree to which you feel your organization is dependent on the GIS to accomplish the mission.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
3. The degree to which the use of the GIS has increased your organization's job satisfaction.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
4. The degree to which the GIS is convenient for your organization to use.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
5. The degree to which the GIS enables your organization to complete the mission easily and efficiently.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
6. The degree to which the GIS provides accurate and reliable information to your organization	1 Not at All	2	3	4	5	6	7 To a Significant Degree
7. The degree to which the GIS contributes to achieving organizational mission goals and objectives.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
8. The degree to which the GIS can be easily adjusted to new conditions, demands and circumstances of the organization.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
9. The degree to which the information provided by the GIS is sufficient for your organization to accomplish the mission.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
10. The degree to which the GIS has been made a long term, integral part of the organization (e.g. is GIS treated as an annual budget requirement, included in personnel position descriptions, local operating procedures, etc.)	1 Not at All	2	3	4	5	6	7 To a Significant Degree
11. How important do you think it is to have a strategy for evaluating GIS performance?	1 Not Important	2	3	4	5	6	7 Extremely Important
12. How important is it to the continued budget support of GIS for you to see tangible evidence of the cost-effectiveness of using GIS technology?	1 Not Important	2	3	4	5	6	7 Extremely Important

GIS MGR VIEW OF GIS PERFORMANCE

1. The degree to which you are currently satisfied with the return on your organization's GIS investment.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
2. The degree to which you feel your organization is dependent on the GIS to accomplish the mission.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
3. The degree to which the use of the GIS has increased your organization's job satisfaction.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
4. The degree to which the GIS is convenient for your organization to use.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
5. The degree to which the GIS enables your organization to complete the mission easily and efficiently.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
6. The degree to which the GIS provides accurate and reliable information to your organization	1 Not at All	2	3	4	5	6	7 To a Significant Degree
7. The degree to which the GIS contributes to achieving organizational mission goals and objectives.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
8. The degree to which the GIS can be easily adjusted to new conditions, demands and circumstances of the organization.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
9. The degree to which the information provided by the GIS is sufficient for your organization to accomplish the mission.	1 Not at All	2	3	4	5	6	7 To a Significant Degree
10. The degree to which the GIS has been made a long term, integral part of the organization (e.g. is GIS treated as an annual budget <u>requirement</u>, included in personnel position descriptions, local operating procedures, etc.)	1 Not at All	2	3	4	5	6	7 To a Significant Degree
11. How important do you think it is to have a strategy for evaluating GIS performance?	1 Not Important	2	3	4	5	6	7 Extremely Important
12. How important is it to continued GIS fiscal support for you to produce tangible evidence of GIS cost-effectiveness?	1 Not Important	2	3	4	5	6	7 Extremely Important

SENIOR MANGEMENT INTERVIEW QUESTIONS

How many people are assigned to your organization (Permanent Authorizations/IPA/Contract)?

What is your estimated annual operating budget?

Would you describe your unit's GIS adoption process as:
1) self-initiated (bottom-up) ;
2) Initiated by HQ and made available to units (bottom-up;
3) Initiated and directed by HQ for operational use (top-down).

What are your sources for funding the GIS implementation?

What persuaded you to support the adoption of GIS technology?

How would you define a successful implementation?

Name the 2 greatest obstacles hindering your unit's ability to achieve long-term GIS success.

Have any procedural, administrative, or physical changes occurred in the unit as a result of the GIS adoption?

How can the Tri-Service CADD/GIS Technology Center serve to improve the GIS investment performance at your installation?

GIS MANAGER INTERVIEW QUESTIONS

When was the original GIS investment made by the organization?

Is the current system the original or were there abandonments? Why was any previous GIS abandoned?

How long has the current implementation been underway? When was 'effective use' first made?

What organizational elements are involved in the GIS implementation?

What is the total environmental acreage managed by your GIS?

How many manning authorizations in the organization are full-time GIS positions?

What is your pay grade? For any other GIS manning authorizations?

Approximate percentage of your projected final database that has been populated?

Approximately unit investment in *physical* GIS database development to date?

Approximate unit investments in GIS software, hardware/peripherals, and Global Positioning System (GPS) hardware/software to date, respectively?

Were explicit GIS objectives established in your organization?

Please describe the nature of any means you employ to formally evaluate GIP performance

What type of organizational implementation mechanism was employed?

Was a formal implementation plan developed?

Please list those who have received training with the intent of being direct GIS users. How many of those trained have continued making direct use? Please explain.

What data dictionary and meta-data standards have been incorporated into your GIS?

Are you anticipating taking part in the NSDI clearinghouse?

What procedures have been established to maintain the currency and integrity of the corporate database?

[Scale of 1-7] How much HHQ guidance have you received for your GIS implementation?

[Scale of 1-7 1=no reliance] How much do you rely on outside technical expertise to use the GIS?

Name the 2 greatest obstacles hindering your unit's ability to achieve long-term GIS success.

How would you describe the level of GIS/Remote Sensing integration?
1) Outside agency performs digital image analysis
2) Digital image analysis performed In-house using stand-alone software
3) Digital image analysis performed concurrent with GIS software (seamless integration)

What software do you use to accomplish your image processing?

How is GPS technology currently being used or planned to be used?

What is the network architecture you use (if any) and how many terminals provide GIS access?

Do you have access to INTERNET?

How can the Tri-Service CADD/GIS Technology Center serve to improve the GIS investment performance at your installation?

Current/planned database inventory
Current/planned GIS hardware inventory
Current/planned GIS software inventory
Remote sensing data inventory

APPENDIX C Statistical Modeling of Personal GIS Adoption Responses

Factor Analysis of the GIS Adoption Response Influences

The unexpected reduction of the statistical population raised concerns for the validity of conducting a factor analysis with 52 variables and 82 cases. At a minimum, the number of cases should exceed the number of variables, otherwise the observational space established to contain the variables would have fewer dimensions than the number of variables and the position of any vector could not be uniquely determined (Goddard and Kirby, 1976). Beyond this fundamental criteria, the number of required cases becomes a subjective issue with a wide range of opinions. Hair et al (1979) recommend the sample size should have at least four times as many observations as there are variables to be analyzed. On the other hand, if there are strong reliable correlations and a few, distinct factors, Tabachnik and Fridell (1989) believe a sample size of 50 may be adequate, as long as there are "notably more cases than factors."

While the cases to variables ratio is relatively low compared to most other field surveys, the advantages afforded by the unique survey design significantly bolsters the statistical validity of the factor analysis in three specific ways (Comrey, 1973). First, the on-site survey administration used in this research lends significant credibility to the data since several of the biases and error variances common to most field surveys were minimized. Secondly, the shared mission and social context of the military installations further reduced the variance otherwise encountered among more disparate organizations. Finally, the survey variables were selected with a priori notions gained through precedent research and should thus lead towards well-defined behavioral latent constructs (Fornell, 1983). However, to accommodate this reduced cases to variables ratio, conservative rules were followed in the data analyses and interpretation of results (Comrey, 1973).

Moore and Benbasat (1991) and Lederer and Sethi (1991) both used factor analysis in an iterative fashion to help derive specific scales which were then used to model information systems use. This research applied the same method by performing common factor analysis with varimax rotation in an iterative fashion to both distill latent groups of GIS use influences and raise the effective cases to variables ratio. After each varimax rotation, the factor matrix was examined for variables which either did not load strongly on any factor or were too complex and loaded highly or relatively equally on more than one factor. Those variables failing to meet the retainment criteria were dropped and the factor analysis performed again.

The first common factor analysis was conducted with the 52 variables across the 82 cases. A varimax rotation was performed to help in maximizing the variance of the loadings on each factor and to aid factor interpretation (Goddard and Kirby, 1976). The number of factors extracted was determined by examining both the results of the scree test and those factors with eigenvalues greater than one (Gorsuch, 1988). Fourteen factors accounted for 66% of the variance in the data set (Table C-1).

Table C-1. First Factor Analysis Results With 52 Variables			
Factor	Eigenvalue	% Expl Var	% CumExpl Var
1	5.73	11.03	11.03
2	3.64	7.00	18.03
3	3.59	6.90	24.93
4	2.82	5.42	30.35
5	2.52	4.84	35.19
6	2.31	4.44	39.63
7	2.29	4.41	44.04
8	2.12	4.08	48.12
9	1.99	3.82	51.94
10	1.81	3.48	55.42
11	1.73	3.32	58.74
12	1.46	2.80	61.54
13	1.37	2.63	64.17
14	1.30	2.54	66.71

Moore and Benbasat (1991) and Lederer and Sethi (1991) used factor loadings of .40 and .35 respectively as their thresholds for deleting a variable. However, a more conservative factor loading threshold of .45 was used in this analysis. The factor loading quality scheme designed by Comrey (1973) and displayed in Table C-2 defines .45 as a "fair" loading.

Table C-2. Quality Rating Scheme for Factor Loadings (Comrey, 1973)		
Orthogonal Factor Loading	Percentage of Variance	Rating
.71	50	Excellent
.63	40	Very Good
.55	30	Good
.45	20	Fair
.32	10	Poor

Using this scheme, twelve variables were found to share little common variance with any one of the extracted significant fourteen factors across the survey population (Table C-3).

Table C-3. Influences Deleted After Initial Factor Analysis	
Influence	Domain
Service headquarters support	External Environment
Cooperation from CADD users	External Environment
Data exchange with other GIS sites	External Environment
Availability of digital data	External Environment
Impact of GIS standards	External Environment
Mandate for GIS use	Organizational Environment
GIS in position description	User Environment
Initial expectations	User Environment
Data format translation	Development/Operations Process
Learning/Applying software upgrades	Development/Operations Process
Ease of DBMS use	GIS
Reliability of the GIS	GIS

After removing these twelve variables from the survey database, a common factor analysis was again performed with the remaining 40 variables across the 82 cases. Using the same factor extraction rules, twelve factors accounted for two-thirds of the variance in the data set (Table C-4).

Table C-4. Second Factor Analysis Results With 40 Variables			
Factor	Eigenvalue	% Expl Var	% Cum Expl Var
1	5.21	13.02	13.02
2	2.92	7.34	20.36
3	2.90	7.25	27.61
4	2.65	6.62	34.23
5	2.08	5.24	39.47
6	1.86	4.65	44.12
7	1.76	4.43	48.55
8	1.64	4.13	52.68
9	1.60	4.00	56.68
10	1.27	3.17	59.85
11	1.23	3.07	62.92
12	1.12	2.83	65.75

Upon examining the rotated factor matrix of the second factor analysis, three more variables failed to satisfy the retainment criteria (Table C-5).

Table C-5. Influences Deleted After Second Factor Analysis	
Influence	Domain
Feedback to GIS developer	Development/Operations Environment
Personal commitment to GIS use	User Environment
Enhanced job prestige	User Environment

After removing these variables, 37 variables remained from the initial set. A third factor analysis was performed with this data set to confirm the twelve factors. Using the same scree and eigenvalue unity tests, 12 factors again emerged, accounting for 66% of the data set variance as was found in the two previous analyses. Each of the 37 variables had factor loadings greater than .45 on only a single factor (Table C-6).

Table C-6. Third Factor Analysis Results With 37 Variables				
Factor	Factor Label	Eigenvalue	% Expl Var	% CumExpl Var
1	Organizational Support	5.27	14.25	14.25
2	Ease of Applying GIS	2.86	7.74	21.99
3	Benefits to User	2.69	7.28	29.27
4	Confidence in Database Quality	2.47	6.69	35.96
5	GPS/Remote Sensing Knowledge	1.98	5.37	41.33
6	Knowledge of Other Adoptions	1.56	4.23	45.56
7	GIS Linkages	1.55	4.19	49.75
8	A-D Conversion Effort	1.54	4.18	53.93
9	GIS Use Access	1.46	3.96	57.89
10	Relative Advantage	1.10	2.98	60.87
11	Procurement of Hardware	1.09	2.96	63.83
12	Extent of GIS Training	1.01	2.77	66.59

The table on the following page (Table C-7) lists the component variables describing each factor, their factor loading and the quality rating derived from the Comrey (1973) scheme described in Table C-2. At this stage of the analysis, all that could be deduced was that the 12 latent factors and their constituent variables were orthogonal to each other in variable space. The research aimed to refine these factors into scales capable of serving as practical indices of the defined, aggregate influences (e.g. 'organizational support'). Any practical index for field application would have to disregard particular factor loadings and simply use the mean of the scales instead of an average weighted by factor loadings. While a method sensitive to the factor scores would obviously be more exact, Gorsuch (1988) finds such a detailed approach to be less generalizable than simply averaging the items that load highly on a factor. In addition, Tabachnik and Fridell (1989) describe this simple method of averaging construct items as "entirely adequate" for many research purposes and it is commonly used in information systems research (Zmud and Boynton, 1991). However, for the results of the factor analysis to be transformed into scales and their means used in regression modeling, they had to be examined for validity, reliability and statistical independence.

Examining the Factor Scales for Validity and Reliability

Venkatraman and Grant (1986) suggest that any good scale being developed for use in survey research should be tested for both reliability and validity since a measure can be valid yet unreliable, but a reliable measure is not necessarily a valid one (Bohrnstedt, 1983). Unfortunately, Zmud and Boynton (1991) found more than two-thirds of the 700 MIS research articles they reviewed reported neither scale reliability or validity and thus "very little at best" can be learned. This research examined these scales for these attributes to facilitate developing a body of constructs that can be exported to other domains for testing and further development.

The validity of a given survey instrument is composed of face and content facets. The validation of the survey instrument prior to administration was only able to assess the face validity of the items and the scope of the influences. Assessing content validity involves reviewing the scales to ensure all aspects of the variables being measured are considered by the instrument. The exploratory nature of this research prevents external validation of the scales which will be tested through future research. However, by looking at each of the scales in Table C-7 and the strength of their factor loadings, there are obvious intuitive relationships between all of the variables which reflect the a priori design.

The most common method of determining the reliability of multiple-item constructs is to measure the internal consistency of the item responses by calculating Cronbach's alpha coefficient (Cronbach, 1951). The alpha coefficient examines the covariances among all the items simultaneously to ensure the items are strongly inter-correlated. Van de Ven and Ferry (1980) argue that in early stages of research, reliabilities of .50 to .60 are "satisfactory" while Nunnally (1978) describes alphas greater than .80 to be indicative of more proven, reliable constructs.

Cronbach coefficients were calculated for the nine multiple-item scales. A reliability rating was assigned based on a scheme derived by consolidating the scales of Van de Ven and Ferry (1980) and Nunnally (1978). Cronbach coefficients greater than .80 were considered 'Superior', those between .60 and .80 were 'Satisfactory', and those between .50 and .60 were 'Marginal'. The results of the reliability analysis demonstrate that 7 of the 9 scales were either satisfactory or superior (Table C-8).

Table C-7. Factor Composition and Loading Strength		
Factor Label Component Variables	Factor Loading	Loading Strength
Organizational Support		
Top management support	.86	Excellent
Continuity of skilled GIS manpower	.78	Excellent
Management perception of GIS cost effectiveness	.74	Excellent
Dedicated GIS Manpower	.67	Very Good
GIS implementation structure	.68	Very Good
GIS integration into standard operations	.66	Very Good
Organizational ability to purchase spatial data	.61	Very Good
Attitude of GIS management	.65	Very Good
Organizational position of GIS manager	.60	Good
Supervisory appreciation for GIS benefits	.52	Good
Ease of Applying GIS		
Functionality of the GIS software	.77	Excellent
Utility of the spatial data model	.72	Excellent
Satisfaction with technical support	.69	Very Good
Availability of GIS technical documentation	.59	Good
Ease of use of the GIS (i.e. point and click)	.48	Fair
Benefits to User		
Ability to perform new tasks	.81	Excellent
Ability to reduce decision risk	.75	Excellent
Ability to produce higher quality products	.74	Excellent
Ability to increase job productivity	.64	Very Good
Confidence in Database Quality		
Confidence in positional accuracy	.83	Excellent
Confidence in attribute accuracy	.79	Excellent
Confidence in data currency	.66	Very Good
GPS/Remote Sensing Knowledge		
Ability to apply GPS knowledge	.81	Excellent
Ability to apply remote sensing knowledge	.73	Excellent
Familiarity with computer systems	.54	Good
Knowledge of Other GIS Adopters		
Knowledge of GIS efforts at other sites	.76	Excellent
Awareness of previous computer efforts	.61	Good
GIS Linkages		
AM/FM/CADD-GIS Links	.78	Excellent
Organic digital database-GIS Links	.73	Excellent
Analog-to-Digital Conversion	.74	Excellent
GIS Use Access		
Ease of physical access to the GIS	.69	Very Good
Work hours available to use the GIS	.56	Very Good
Requests for GIS chauffeuring	.57	Very Good
Relative Advantage to Using GIS	.70	Very Good
Procurement of Capable Hardware		
Utility of GIS hardware	.62	Good
Importance of GIS champion	.51	Fair
GIS Training	.55	Good

Table C-8. Reliability of the Multi-Item Adoption Response Scales			
Influence Scale	Scale Items	Alpha	Reliability Rating
Organizational Support	10	.89	Superior
Ease of Applying GIS	5	.81	Superior
Benefits to User	4	.83	Superior
Confidence in Database Quality	3	.88	Superior
GPS/Remote Sensing Knowledge	3	.70	Satisfactory
GIS Linkages	2	.74	Satisfactory
GIS Use Access	3	.62	Satisfactory
Knowledge of Other GIS Adoptions	2	.56	Marginal
Procurement of Capable Hardware	2	.51	Marginal

Examining the Factor Scales for Independence

Comrey (1973) cautions that when the raw means of factors are used in lieu of factor scores, these means may be correlated even if the factor solution is orthogonal. Therefore, scale independence was tested by first calculating the respondent's raw scale averages for the twelve scales and examining their correlations(Table C-9). The results indicate that no pair of scales shared a Pearson correlation coefficient greater than .50 and thus all qualified as independent variables for regression modeling (Johnston, 1984).

Table C-9. Correlation Matrix of the GIS Adoption Response Scales												
Factor Scale	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
Organizational Support	1											
Ease of Applying GIS	.11	1										
Benefits to User	-.04	.34	1									
Confidence in DB Quality	.31	.50	.49	1								
GPS/RS Knowledge	.25	.46	.30	.36	1							
GIS Linkages	.30	.22	-.03	.19	-.01	1						
A-D Conversion Effort	.17	.02	-.05	.01	.05	.02	1					
Adoption Knowledge	.11	.21	.15	.20	.14	.12	.15	1				
GIS Use Access	.12	.10	.09	.25	.00	.14	.20	.35	1			
Relative Advantage	.12	.10	.19	.20	.18	.02	.21	.14	.07	1		
Capable Hardware	.19	.24	.14	.21	.21	.10	-.08	.20	.01	.15	1	
GIS Training	.30	.19	.00	.13	.16	.11	.35	.28	.03	.03	.12	1

The factor analysis procedure collapsed the original 52 variables gathered from the environment, process and the system domains into 12 distinct clusters of correlated variables. To render the factors more generalizable, each of the unidimensional factors were examined for reliability and statistical independence using the Cronbach's alpha and Pearson correlation statistics, respectively. All of the scales were found to

be both reliable and independent. Therefore, the arithmetic means of the twelve scales scored by the 82 respondents could be used as valid and reliable indices of their respective opinions (Kim and Lee, 1991). In addition, these means could be treated as independent variables within a multiple regression analysis without serious concern for multicollinearity.

Analysis of the Dependent Variable Scales

Descriptive statistics were compiled for the two scales capturing direct and indirect GIS use employed in the research (Table C-10). Insignificant differences were discovered in the means and standard deviations for the respective scale items. In interpreting the population's average response to the scale item which used qualitative descriptors, individuals were found to be making direct use of the GIS about 3-4 times a week. Relatively speaking, the average amount of direct GIS use was much higher than the amount of indirect or "chauffeured use".

Table C-10. Descriptive Statistics for 'Extent of GIS Use' Scales

Variable	Mean	Stand Dev
Frequency of direct GIS use (Integer scale of 1-7)	4.90	2.11
Frequency of direct GIS use (Qualitative 7-point scale)	4.75	2.10
Average of two-item 'Extent of Direct GIS Use' scale	4.82	2.11
Frequency of indirect GIS use (Integer scale of 1-7)	2.39	1.78
Frequency of indirect GIS use (Qualitative 7-point scale)	2.39	1.65
Average of two-item 'Extent of Indirect GIS Use' scale	2.39	1.71

The calculated Cronbach coefficients for the 'Extent of GIS Use' scales were .92 for direct use and .91 for the indirect use. This indicates both the scales could be considered extremely reliable.

The GIS use scales were then examined for unidimensionality. This step was not necessary for the 12 influence scales since their dimensionality was already confirmed. A common factor analysis of the GIS use responses clearly delineated the dual dimensions to GIS use (Table C-11).

Table C-11. Factor Analysis of 'Extent of GIS Use' Scales

Scale Item	Factor 1 Loadings	Factor 2 Loadings
Frequency of direct GIS use (Integer scale of 1-7)	.88	.04
Frequency of direct GIS use (Qualitative 7-point scale)	.88	.01
Frequency of indirect GIS use (Integer scale of 1-7)	-.04	.88
Frequency of indirect GIS use (Qualitative 7-point scale)	.10	.88
Eigenvalue	1.58	1.57

Descriptive statistics were also compiled for eight-item 'GIS User Satisfaction' scale (Table C-12). Again, no remarkable differences were discovered between the means and standard deviations of the items.

Table C-12. Descriptive Statistics for the 'GIS User Satisfaction' Scale

Variables (Integer Scale of 1-7)	Mean	Stand Dev
Your dependence on GIS to perform your mission tasks	4.71	1.89
Your use of the GIS increases your job satisfaction	5.58	1.37
The GIS is convenient for you to use	5.24	1.62
The GIS enables you to perform tasks more easily	5.02	1.49
The GIS provides you accurate and reliable information	4.77	1.59
The GIS is contributing to organizational goals	4.51	1.64
The GIS can be adjusted to new demands and conditions	4.48	1.61
The GIS provides you sufficient data for task completion	4.89	1.49
Average of eight-item 'GIS User Satisfaction' scale	4.90	1.59

The calculated Cronbach alpha coefficient of the GIS User Satisfaction scale was .89 meaning the covariances of the eight items were highly significant and indicative of a scale that is very well suited for advanced research applications (Nunnally, 1978). The Cronbach analysis also showed that deletion of any of the items only lowered the alpha, therefore all items were retained. The results of an inter-item correlation analysis confirmed that all the items were inter-related at least at the .01 level of significance. The final analysis to be performed was examining the satisfaction scale for unidimensionality (Table C-13). All items had a factor loading far exceeding .50, so it can be concluded the eight survey items were describing the same single construct of GIS user satisfaction (Rivard and Huff, 1988).

Table C-13. Factor Analysis of 'GIS User Satisfaction' Scale

Scale Item	Factor Loading
Your dependence on GIS to perform your mission tasks	.69
Your use of the GIS increases your job satisfaction	.71
The GIS is convenient for you to use	.65
The GIS enables you to perform tasks more easily	.84
The GIS provides you accurate and reliable information	.67
The GIS is contributing to organizational goals	.75
The GIS can be adjusted to new demands and conditions	.69
The GIS provides you sufficient data for task completion	.74
Eigenvalue	4.15

The two dependent variable scales of 'Extent of GIS Use' and 'GIS User Satisfaction' were found to be extremely reliable, unidimensional, and their external or predictive validity was confirmed through previous information systems research. Therefore, their raw means could be treated as highly credible estimates of the individual GIS user's responses to GIS adoption. To clarify the strength of the relationships between the three dependent variable scales (Direct Use, Indirect Use and GIS User Satisfaction), a correlation analysis was performed on the means of the three scales for the 82 respondents (Table C-14).

Table C-14. Correlation Table for GIS Adoption Response Scales				
	Direct Use	Indirect Use	Combined Use	Satisfaction
Direct Use	1.0			
Indirect Use	.05	1.0		
Combined Use	.79**	.66**	1.0	
Satisfaction	.65**	.04	.52*	1.0
* .001 Level of Significance ** .0001 Level of Significance				

Regression Modeling of GIS Adoption Responses

A stepwise multivariate regression statistic was used to determine which of the influence scales explained the most variance in the dependent variables. The default correlation significance level for variables to be included in the regression model was .15. However, this was raised to .05 to ensure the highest confidence could be placed on those scales identified as significant predictors of successful GIS adoption responses. A stepwise regression was performed using three different dependent variables; 'Extent of Direct GIS Use', 'Extent of Combined GIS Use' (the sum of direct and indirect use); and 'GIS User Satisfaction' (Tables C-15 through C-17).

Table C-15. Model Parameters for 'Extent of Direct GIS Use'

Variables	Standardized b	t-value	Probability > |t|
GIS Use Access	.62	5.98	0.0001
GIS Training	.34	3.99	0.0001
User Benefits	.32	2.10	0.03
N=82 Cum Adj r^2 = .42		F value = 20.99 Probability > F = 0.0001	

Table C-16. Model Parameters for 'Extent of Combined GIS Use'

Variables	Standardized b	t-value	Probability > |t|
GIS Use Access	.72	4.85	0.0001
GIS Training	.36	2.96	0.004
GIS Linkages	.26	2.07	0.04
N=82 Cum Adj r^2 = .33		F value = 14.64 Probability > F = 0.0001	

Table C-17. Model Parameters for 'GIS User Satisfaction'

Variables	Standardized b	t-value	Probability > |t|
Benefits to User	.31	3.12	0.002
Confidence in Database Quality	.18	2.89	0.005
GIS Use Access	.17	2.73	0.007
Organizational Support	.14	2.14	0.03
GIS Training	.14	2.94	0.004
N=82 Cum Adj r^2 = .50		F value = 17.34 Probability > F = 0.0001	

Regression Modeling of GPS/Remote Sensing Capable GIS Users

Table C-18. Model Parameters for 'Extent of Direct GIS Use' by 'GPS/Remote Sensing Capable' Users

Variables	Standardized Beta	t-value	Probability > |t|
GIS Use Access	.580	2.949	0.009
GPS/Remote Sensing Knowledge	.479	2.898	0.01
Intercept	4.011	8.748	0.0001

RMSE = 1.11
Cum r^2 = .581
Cum Adj r^2 = .529
F value = 11.119
Probability > F = 0.0009

Table C-19. Model Parameters for 'Extent of Direct GIS Use' by 'GPS/Remote Sensing Not Capable' Users

Variables	Standardized Beta	t-value	Probability > |t|
GIS Use Access	.691	3.503	0.001
Intercept	3.543	9.481	0.0001

RMSE = 1.873
Cum r^2 = .283
Cum Adj r^2 = .260
F value = 12.270
Probability > F = 0.001

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13.ABSTRACT *(Maximum 200 words)*

A comprehensive study of relatively mature geographic information system (GIS) implementations across 38 field-level organizations on tri-service installations was conducted in 1994. The research aimed to capture responses to both the organizational and personal decisions to adopt GIS technology. A comprehensive survey protocol was employed to include quantitative instruments and structured personal interviews. Senior organizational managers, GIS managers, and all available direct and indirect GIS users were personally interviewed in each of the organizations. A number of significant implementation process trends noted highlighted the dire need for tri-service personnel to acquire greater awareness of social and technical actions required for successful adoption of GIS technology.

All direct users of the implemented GIS were administered a survey which captured their backgrounds, facilitating and inhibiting issues influencing their GIS use, their degree of reported satisfaction and system use, and their opinions of remote sensing and Global Positioning System technology issues. Factor analysis revealed a set of 12 common factors influencing GIS use across tri-service installations. Stepwise multivariate regression identified five specific factors explaining the most variance in GIS use and user satisfaction. The results provide unprecedented capability to more aggressively monitor GIS implementations and design more effective prescriptions for enhanced GIS performance.

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